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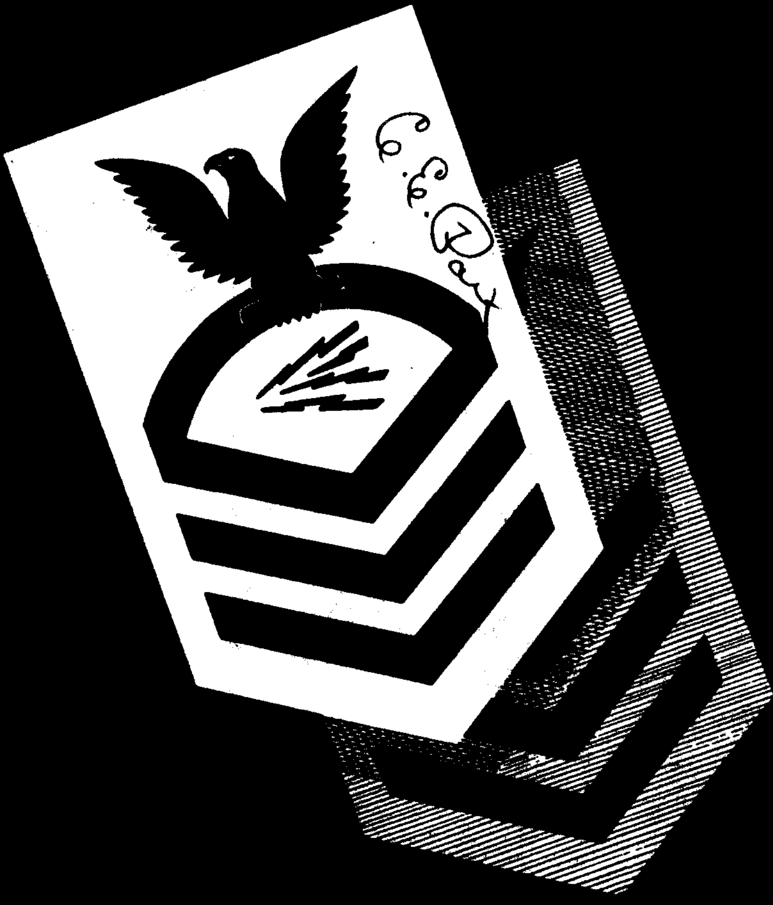

RADIOMAN 1 & CHIEF

NAVY TRAINING COURSES

NAVPERS 10229

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RADIOMAN 1 AND C

Prepared by

BUREAU OF NAVAL PERSONNEL

NAVY TRAINING COURSE

NAVPERS 10229

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PREFACE

This book is written for Radiomen of the United States Navy and Naval Reserve who are seeking advancement in rating to RM 1 or RMC. The first chapter contains a general survey of communication systems, including Army, Air Force, Coast Guard, and the organization and functions of the Federal Communication Commission. Chapter 2 contains information on radio wave propagation and provides a discussion of nomograms and frequency tables. It will prove particularly valuable in selecting the correct frequency for transmission. Other chapters cover the range of Navy transmitting and receiving equipments, including radiotelephony and teletypewriter.

Although the first chapter briefly discusses the various methods and systems used by the Naval Communication Service, no effort is made to deal with Navy communication procedures. For a review of that information, the reader should study the Navy Training Course, *Radioman 3 and 2,* NavPers 10228, and appropriate communication publications. Commercial communication procedure is treated in chapter 13, "Abstracting and Accounting."

As one of the Navy Training Courses, this book represents the joint endeavor of the Naval Reserve Training Publications Center of the Bureau of Naval Personnel and the office of the Chief of Naval Communications.

STUDY GUIDE

The table below indicates which chapters **of this book apply** to your rating. To use the table, follow these rules:

1. Select the column which applies to your rating. If you are in the Regular Navy you will use the column headed "RM" which is the general service rating. If you are a member of the Naval Reserve you will use the column headed by your particular emergency service rating RMN or RMT.

2. Observe which chapters have been marked in your RATING column with the number of the RATE to which you are seeking advancement.

3. Study those particular chapters. They include information which will assist you in meeting the qualifications for your rating. (See appendix II of this book for a complete list of qualifications for advancement in rating.) To gain a well-rounded view of the duties of the general service rating, it is recommended that you read the other chapters of this book, even though they do not pertain directly to your rating.

4. Here is an example: If you are a member of the Naval Reserve studying for advancement in rating to Radioman T second you will select the column headed RMT. Following this column down you will observe that you must study chapters 1, 8, 12, 13, and 15.

Chapter	*RM*	*RMN*	*RMT*
1	1,C	1,C	1,C
2	1,C	1,C	
3	1,C	1,C	
4	1,C	1,C	
5	1,C	1,C	
6	1,C	1,C	
7	1,C	1,C	
8	1,C	1,C	1,C
9	C	1,C	
10	1,C	C	
11	1,C	1,C	
12	1,C	1,C	1,C
13	1,C	1,C	1,C
14	1,C	1,C	
15	1,C	1,C	1,C

READING LIST

NAVY TRAINING COURSES

Radioman 3 & 2, NavPers, 10228
Introduction to Radio Equipment, NavPers 10172
Electricity, NavPers 10622
Quartermaster 3 & 2, NavPers 10023
Sonarman 3 & 2, NavPers 10125
Electronic Technician's Mate 3, NavPers 10145
Electronic Technician's Mate 2, Vol. 1, NavPers 10143–A
Typewriting Manual, NavPers 10609

USAFI TEXTS

United States Armed Forces Institute (USAFI) courses for additional reading and study are available through your Information and Education Officer.* A partial list of those courses applicable to your rate follows:

Number	*Title*
EM 404	*Physics III (Electricity)*
EM 415	*Radio for Beginners*
EM 416	*Electricity for Beginners*
EM 725	*Fundamentals of Typewriting*
EM 726	*Business Typewriting*
EM 962	*Principles and Practice of Radio Servicing*
EM 469	*Electricity and Magnetism*

*Members of the United States Armed Forces Reserve components, when on active duty, are eligible to enroll for USAFI courses, services, and materials if the orders calling them to active duty specify a period of 120 days or more, or if they have been on active duty for a period of 120 days or more, regardless of the time specified in the active duty orders.

CREDITS

Information concerning the operation and maintenance of teletypewriter equipment appears in this book through the courtesy of the Teletype Corporation, Chicago, Ill.

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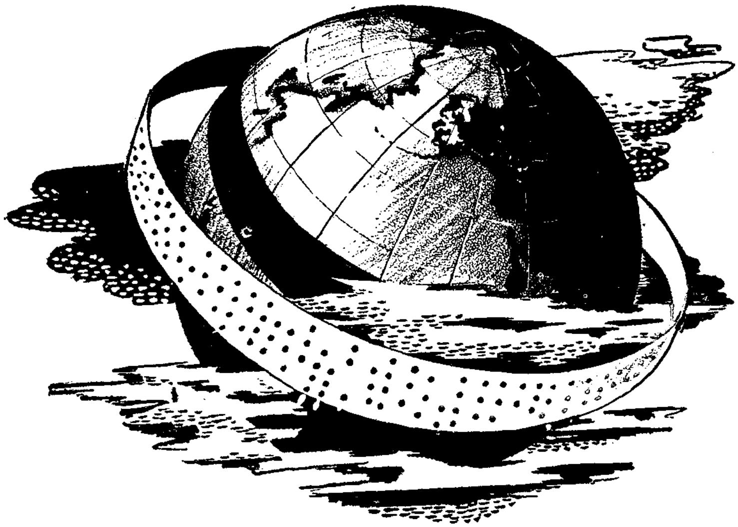
RADIOMAN 1 AND C



CHAPTER 1

COMMUNICATION SYSTEMS

SERVING COMMAND

In modern warfare, no commander can exercise control of more than a handful of men by his physical presence. To receive information upon which to base decisions, to transmit commands, and to keep his ship in all respects ready for combat, the commanding officer must rely upon communications. In this day of huge task forces and armadas of supporting aircraft, effective communications usually means RADIO communications.

To clearly understand his responsibilities, every rated Radioman and striker must know the Naval Communication Service—its organization, functions, and facilities. In addition, the RM1 and Chief must be familiar with commercial communication practices and the communication organization of other branches of the Armed Forces.

The mission of the Naval Communication Service is to provide reliable, speedy and accurate communications for the Navy. In carrying out this mission, NCS has two obligations: First, to serve command; and second, to serve administration. Command is responsible for combat training of the operating forces, and for their direction before and during conflict with the enemy. Administration provides personnel, materiel, and all the other facilities necessary to give command the freedom of action necessary for combat. This means training personnel and providing weapons, fuel, food, bases, repair yards, supply depots, etc.

The policy of naval communications is to provide and maintain a naval communication system based on war requirements. This includes facilities for furtherance of safety at sea and in the air, and cooperation with American commercial communication activities to increase their military value in time of national emergency. This policy requires an adequate shore communications system and facilities within naval operating forces for rapid and effective communications. It also provides for Joint communications with the Army, Air Force, Coast Guard, and Marines. It must establish effective combined communications with allied fighting services.

SHORE COMMUNICATION SYSTEM

There are five primary communication centers in the United States Navy shore communication system. These are strategically located throughout the world, furnishing complete radio coverage of the major portions of the world's ocean areas. These five primary centers and their radio call signs are: Washington (NSS), San Francisco (NPG), Guam (NPN), Honolulu (NPM), and Balboa (NBA).

In addition to other circuits, each of these centers maintains a primary fleet broadcast for the delivery of traffic by the Fox broadcast method to all naval ships in the ocean areas which each center serves. The broadcasts consist of a very high power (350 to 500 kw.) VLF or LF keyed simultaneously with five high-power high frequencies. These frequencies are Boehme keyed at manual speeds not exceeding 25 w. p. m. The primary fleet broadcast is the most important method of delivery of command and administrative traffic to the forces afloat.

A primary general broadcast, similar to the fleet broadcast, is also maintained by each primary center. Information transmitted includes:

1. Time signals.
2. Weather.
3. Hydrographic warnings.
4. Notices to mariners.
5. Some press.
6. Merchant ship traffic.

To move traffic from ships into the shore system, a ship-to-shore circuit high-power HF using the 4235 kc. series, manually keyed for long distance delivery, is used. There are also local harbor circuits, as necessary, and to link the primary centers together, multichannel RATT and voice trunk circuits are used.

Although the primary communication centers are the main structural members of the shore communication system, their operations must have the support of major communication centers and minor communication centers.

Radio and land-wire circuits from primary communication centers connect with major communication centers throughout the world. These major centers, in addition to other circuits, maintain facilities for a secondary fleet broadcast of limited area coverage; a secondary general broadcast of limited area coverage; and local harbor circuits and high-power HF ship-to-shore circuits. At certain major communication centers, a high-power HF duplex radioteletypewriter circuit is available for use with fleet or force commanders.

Primary and major communication centers are connected to minor communication centers by radio and land-wire circuits. Fleet communications support is rendered from only a few minor centers. All three types of communication centers have circuits serving tributaries also called subscribers or users.

NTX

One of the major components of the shore communication system is the Naval Teletypewriter System (NTX). This teletypewriter system is made up of certain radio trunk circuits—particularly overseas channels and practically all land-wire circuits of the shore communication system. Within NTX there are primary, major, and minor relay stations as well as tributary offices. These primary, major, and minor relay stations are integral components of their respective communication centers. In short, each primary communication center has an associated primary relay station, each major communications center has an associated major relay station, etc.

NTX uses the tape relay method for handling traffic. Messages are received and routed to destination in tape form by semiautomatic or automatic equipment. Tapes are routed by means of routing indicators which are directional in nature. These indicators, a group of three to seven letters, are assigned to various stations and activities within NTX.

Teletypewriter systems in the Armed Forces use two methods of routing traffic, free and channelized. In the free method (used by Army and Air Force networks) traffic is forwarded by the most direct means, without reliance on predetermined routing doctrine. In the channelized method, the flow of traffic and relay responsibilities are in accord with a specific prearranged plan, or routing doctrine. This method of traffic handling is

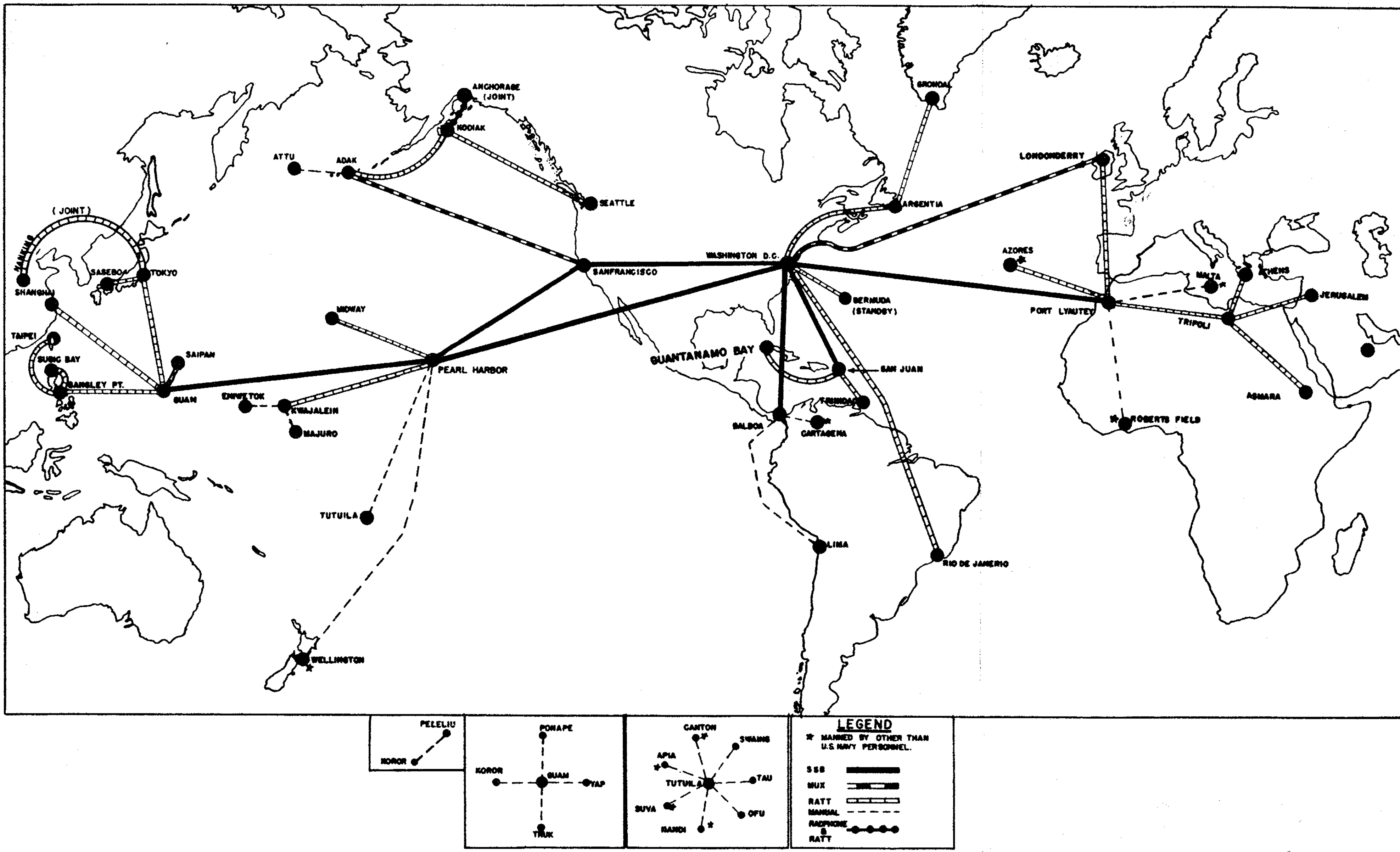


Figure 1.—Naval radio circuits.

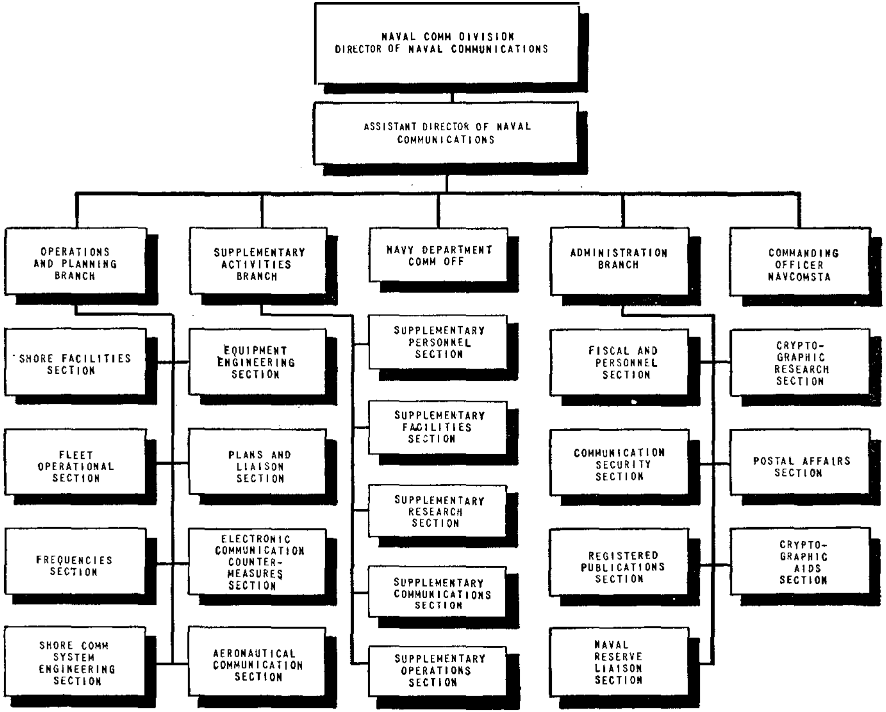


Figure 2.—Organization of the Naval Communication Service.

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so designed that tape processing at relay stations is reduced to a minimum.

TWX is another form of teletypewriter service used to supplement NTX. This service is furnished by the telephone company on the same basis as long distance telephone calls. TWX communication is by teletypewriter only and no duplex service is offered.

TWX subscribers are connected to the central office of the telephone company where communication is established with other TWX stations. While the two stations are connected, the traffic moves in either direction, but not in both directions at the same time.

Tape messages can be transferred between NTX and TWX very easily as they both use the same equipment.

SHIP TO SHORE

Traffic between shore stations and ships is transmitted by radiotelegraph, radiotelephone, and radioteletypewriter. The major portion of the traffic is handled by CW using the broadcast method. During peacetime, the receipt (R) method is used extensively, especially for traffic between ships. The intercept (I) method is available, but almost never used.

This is only a broad outline of the Navy communication organization. If you feel the need of further review, consult the training manual, *Radioman 3 and 2,* and *Joint Communication Instructions.*

JOINT COMMUNICATIONS

To coordinate communications among the various branches of the Armed Forces, the Joint Communications-Electronics Committee (JCEC) has been established. This committee includes high-ranking communications men from each of the services; the Navy's representative is the Director, Naval Communications. Under the direction of JCEC, communication personnel and material are made available for common use of all the services, and unnecessary duplication of communication facilities is avoided. Regardless of the service which constructs, maintains, and operates a particular communication facility, circuits and channels are allocated to other services and their commands as necessary. The circuits may be used on a full-time or part-time basis, whichever the command requires. In any case, when a circuit connects activities of two or more of the services, only one service is responsible for maintenance of facilities between those communication points. Under Joint communication practices, the Navy Teletypewriter System (NTX), for instance, handles traffic for Coast Guard, Air Force, and Army activities when NTX is in better position to transmit such traffic than the regular networks of those services. NTX also serves other government agencies.

Joint communication procedures are promulgated in Joint Army-Navy-Air Force Publications (JANAP's), which insure uniform communication doctrine for use by all the Armed Forces.

The need for joint communications became apparent in the early stages of World War II when Army and Navy installations frequently duplicated each other in the same locations, and differences in procedure made efficient communications between the services virtually impossible. The establishment of Joint communication centers, especially at advanced bases and in rear areas, went a long way toward eliminating these difficulties. The establishment of a Joint communications board (now JCEC) started the trend toward joint communications which continues under armed forces unification.

ARMY COMMUNICATIONS

By using Joint procedures, the Army and Navy and other branches of the Department of Defense exchange information rapidly and with a minimum of processing. Basically, both Army and Navy use the same methods of transmitting traffic, but a particular method may come in for greater use by one service than by another. In the field of electrical communications, both the Army and Navy have radiotelegraphy, radiotelephony, teletypewriter, American Morse telegraphy, telephone, and facsimile. The Army uses pigeon communications (as did the Navy for some purposes at Okinawa), but its application is limited. American Morse telegraphy is a method almost completely replaced in both services by teletypewriter communications.

One of the chief problems of Army communications is the amount of time required to install communication facilities. Radiotelegraph has been found to be the most suitable for quick installation, and along with radiotelephone is used when a command post is first established. As soon as possible, these methods are supplemented, or replaced, by wire systems. While it takes more time to install a wire system, once completed it is capable of greater flexibility and can carry a greater volume of traffic for a given number of personnel. It has a great advantage over radio communications in that messages transmitted by wire cannot be intercepted by the enemy unless the enemy physically connects apparatus to the wires carrying the messages. This emphasis on wire systems in combat areas is one of the major differences in Army and Navy assault communications. The Navy, operating at sea, must necessarily use visual and radio communications when in combat.

Army communications is the direct responsibility of the Army Signal Corps which furnishes communications to activities in the continental United States (zone of interior) and to the various theaters of operation. For signal communications purposes, the rear area of a theater is designated the communication zone, and the forward area, where armies are active in the field, the combat zone. The man who is responsible for the installation, maintenance, and operation of communication facilities in all zones is the Chief Signal Officer.

The Chief Signal Officer

The Chief Signal Officer can be compared to the Director, Naval Communications (DNC). His responsibilities to the Secretary of the Army and the Chief of Staff are equivalent to DNC's responsibilities to the Secretary of the Navy and the Chief of Naval Operations. The integration of the entire Department of the Army signal communications system is his direct responsibility. This requires standardization of equipment and procedures as well as technical direction and control of theater signal communications systems and signal communications in combat areas. He is also responsible for training signal communications personnel and the procurement of signal communications supplies.

He has direct technical control of that part of the Army signal communications system known as the Army Command and Administration Network (ACAN). In Joint communications, he maintains liaison with communication departments of the Navy and the Air Force, and all three services use ACAN as necessary.

ACAN

The Army Command and Administrative Network (ACAN) is made up of all long-distance circuits in the zone of the interior and to overseas commands including the Alaskan communication system. These circuits link the Department of the Army to theaters and overseas departments and commands as well as such other communication centers and relay stations as may be necessary. The construction, maintenance, and operation of this network is the direct responsibility of the Chief Signal Officer and is performed by personnel under his direct control.

Those stations forming the distant end of overseas circuits (which are also a part of the Theater Signal Communication System) are operated by troops under control of the theater commander. Nevertheless, these stations are under the technical control of the Army Command and Administrative Network.

Within the continental United States, ACAN uses, primarily, circuits leased from commercial communication companies, except when military circuits are more desirable for purposes of training or security. (Almost all traffic is handled in the continental limits by teletypewriter.) ACAN constructs any signal communication facilities which cannot, or should not, be obtained by lease from commercial companies.

The Chief Signal Officer allocates circuits of ACAN for the use of major commands and activities. For convenience or economy of operation, major commands are sometimes directed to maintain and operate a portion or all of certain circuits—especially when those circuits have been allotted to the major command.

ACAN serves other Government departments and agencies when this can be done without undue delay to military traffic. It also makes necessary arrangements for contact with commercial communications networks and the refile of messages with such networks.

ACAN also organizes and maintains special teams for the installation of unusual and special equipment. These teams are sent throughout the Army to install equipment when the installation is beyond the normal means of the theater or major command. The teams remain after the equipment is installed for a "breaking-in" period to instruct the operating and maintenance personnel who will be assigned to the equipment.

THEATER SIGNAL COMMUNICATIONS

In the domestic zone, existing commercial communications are expanded to meet the needs of the military. In the theater, however, all signal communica-

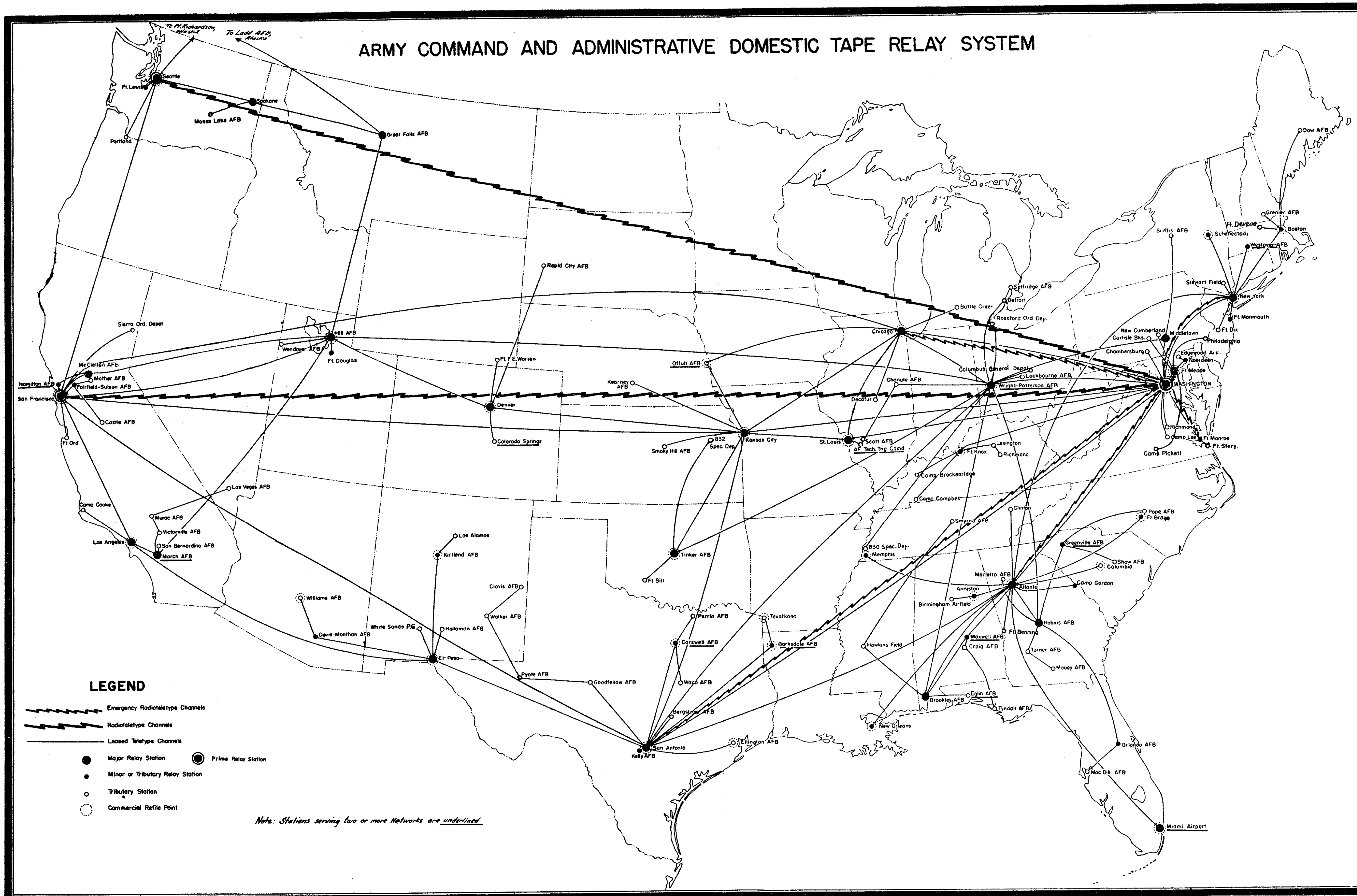

Figure 3.—ACAN.

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tions are controlled by the military, and the major part of such communications is operated, constructed, and maintained by the military. Within the theater, the manner of controlling signal communications in the combat zone and in the communication zone is somewhat different. In the combat zone each commander controls the signal or communication troops who maintain and operate signal communications for the command. In the communication zone, conditions more nearly approach those in the zone of the interior.

In the communication zone, the theater signal officer organizes the theater signal communications service. Each unit in this zone is left only those signal or communication troops necessary to construct, maintain, and operate its local signal communications facilities and those point-to-point radio circuits which the command requires for operation. All other signal or communication troops are pooled to form the theater signal communications service. The commander of the theater signal communications service, operating directly under the theater signal officer, establishes the long-distance signal communications system in the communication zone. This system consists of wire facilities, radio facilities, combinations of the two, and courier service. The system also operates signal centers and long-distance switchboards. Local switchboards are installed in localities where one large switchboard can replace several small ones, improving telephone and teletypewriter service.

Examples of the signal communications for which troops are left with units in the communication zone are: Operational radio circuits between elements of the Air Forces, Airways and Air Communications Service circuits, local communications within a port or depot area, antiaircraft artillery operational circuits and aircraft warning circuits.

The theater signal communications system serves the entire theater and furnishes long-distance signal communications to all units and activities. It is planned with a view to expansion in those areas where activity may be expected to increase. In the long-distance system the route of long-distance circuits will often follow railways to simplify construction and maintenance. The construction of facilities which will eventually be incorporated into the theater signal communication system is pushed forward into the combat zone as rapidly as possible and as far as the tactical situation will permit. The theater signal communication system must always reach at least to the general line formed by the rear boundaries of armies. It is always pushed forward to give signal communications to the headquarters of an army group, and continues constructing facilities well ahead of the army group headquarters. When the theater network is being constructed within the combat zone the theater signal communications system uses routes employed by major units, increasing existing facilities, rather than duplicating them.

The theater signal officer coordinates construction so that the signal communications of the major unit is not interfered with. He arranges a suitable time and procedure to incorporate all facilities into the theater signal communications system without interfering with the signal communications of the major unit.

In planning and constructing the theater signal communications system, provision is made for other Government services operating in the theater and for the press. If a theater is allied, provision is made for coordinating the system to meet the needs of all allies in the theater, at the same time retaining one integrated system for the whole theater. Where one ally is responsible for a specific sector, responsibility in that sector may be delegated to that ally by the supreme theater signal officer.

The theater signal officer is responsible for operation of those stations which join the theater signal communications system with ACAN. He follows, of course, the policies and instructions of ACAN. The theater signal officer represents the theater commander in all matters concerned with radio frequencies and radio call signs. He also provides a monitoring service to enforce frequency and procedure discipline and is in charge of radio countermeasures and radio deception plans.

GROUND FORCES COMMUNICATIONS

Success of the ground forces in the field requires fire, movement, and physical contact with the enemy. Control of units down to the individual squad and soldier is accomplished chiefly by signal communications. The methods used, and the manner of applying those methods, are adapted to the problems created by the control of fire and movement of widely dispersed forces. In many instances, these forces are in contact with the enemy. For this reason, and because units often have occasion to act independently, each ground force commander is given the necessary troops to provide signal communications required to complete the unit's combat mission. The nearer the unit operates to the front, the more clearly this principle applies and the more closely it is followed.

In larger units (corps or army) the task of providing signal communications extends beyond the combat requirements of the unit itself and includes other signal communications needed to accomplish the overall mission. Army, army group and sometimes even corps may take advantage of connection to the theater signal communications system to provide part of the required trunk communications.

The division is the smallest unit to which Signal Corps troops are normally assigned, although some special purpose units, such as the engineer special brigade, have a signal company. In regiments and smaller units, the signal communications personnel belong to the arm, or service, of the unit (infantry, artillery, engineers, etc.). The fact that all personnel engaged in signal communications in the ground forces are not of the same arm or service demands a greater emphasis on cooperation than might otherwise be necessary. This is especially true since the signal communications system of each unit must fit into that of the next larger unit to provide an integrated system.

Signal communications in the ground forces can be divided into three parts:

1. Command and administration.
2. Control of fire and movement, or both.
3. Liaison with supporting forces such as the Navy or Air Force.

Command and Administration

Each commander, from army group down to battalion, must have command communications with each next subordinate unit. Since each commander is provided the necessary facilities, command communications become his direct responsibility. However, the signal officer (much as a Navy communication officer) assumes this responsibility when he acts in the name of his commanding officer.

While each system is primarily for the use of the commander of that echelon of command, it is designed and planned to fit into the signal communications system of the next higher commander. The responsibility for the establishment of signal communications is not limited by tactical areas. Therefore, signal communications troops from the superior unit frequently work forward of the command posts of the next subordinate unit. It is normal for division signal officers to furnish radio teams at regimental headquarters for operation in the division command network. In the same manner, wire construction teams from the division signal company are always attached to regiments to extend the division wire system.

The command and administrative system generally serves command, administration, and supply. This is especially true in units smaller than an army where supply and administration agencies are located, for the most part, near the command posts of the headquarters which they serve. In the army or army group a separate signal communications system is often required for supply, evacuation, and administrative agencies. Although this latter system operates as an integral part of the army signal communications service, it is usually planned and engineered as a separate project. This is so because the facilities served are not normally in the vicinity of command posts or signal communications routes connecting command posts. Types of installations served by this particular network are replacement centers, hospital areas, depots, repair shops, and port installations. It also serves brigades, groups, battalions and separate companies of the supporting and service troops of a modern field army.

Fire and Movement Control

The communication channels provided in lower combat units of the ground forces are primarily for fire and movement control. Examples of the use of such channels is the fire-control system employed by the field artillery and the infantry battalion command network. Field wire and field-telephone equipment, backed up by small portable and vehicular radio equipment, provides the basis for these systems. Another type of fire and movement control circuit is the so-called "through" circuit from a higher headquarters to an observation post or other installation well forward. Special circuits required for intelligence purposes also fall into this class, as do liaison circuits between supporting artillery and supported units.

Communications for Support

The principal support for ground forces is provided by the tactical air command. Wire and radio relay operational channels are normally used for processing air request missions and for the exchange of battle information and intelligence. In addition, a separate radio communications system may be provided at army, corps, and division level for insuring this support. This separate radio communications system provides for radio nets that link the air-ground operations section at the Joint operation center directly with corps, divisions, and ground liaison officers stationed with units of the tactical air command. The Joint operations center is manned by ground forces, air forces, and Navy personnel (when necessary).

During amphibious operations, support is given by the Navy, and support communications must be provided for both naval gunfire and naval air support. Communications plans for this must be prepared well in advance of an operation in order that the necessary personnel and equipment can be provided at the proper places and at the proper time. Each operation must be planned separately since the number and type of circuits required will depend on the number of naval units available for support, the number of landing beaches, etc.

Since support by other forces is vital to the success of any operation, it is necessary that support communications be the best obtainable. The signal officer of the ground force unit must, by close liaison with the supporting units, insure the establishment of adequate signal communications.

AIR FORCE COMMUNICATIONS

The increasing speed and range of aircraft demands that the Air Force be supported by the most rapid, flexible, and efficient communication system possible. In the Air Force, as in the Navy, radio is the primary means of communications. Wire communications are used between ground installations and at various points in the field as operations progress.

AACS

The most important communications element in the Air Force is the Airways and Air Communications Service (AACS). This is the agency, under the direction of the Commanding General of the Air Force, which is responsible for a continuous system of airways communication services along military air routes. These communication services provide facilities for point-to-point, air-ground-air, airdrome control, and meteorological communications. AACS establishes cryptographic sections, message centers, direction-finding facilities, instrument approach landing facilities, and radio and radar aids to air navigation.

AACS handles all message traffic pertaining to movement and operation of military aircraft except those actually engaged in combat operations. The collection and distribution of communication traffic required by the Air Weather Service also comes under AACS.

Air Communication Officer

The duties of the Air Force communication officer are about the same as those of an Army signal officer. However, the Air Force communication officer has a number of duties in connection with electronic devices which are not generally the concern of the Army signal officer, or the Navy communication officer.

Among the electronic devices which come under his cognizance are ground radar reporting and control systems, electronic navigational systems (radio ranges, beacons, loran, etc.), and automatic bomb-dropping mechanisms.

Functioning under the communication officer are assistants and advisers called communication unit commanders. Each unit commander conducts the training and operation of his unit according to the orders of the communication officer. Unit commanders and the communication officer work as a team, each acting for the other when necessary. However, responsibility for the conduct of signal communications operations cannot be delegated by the communication officer to any assistant. The duties of a unit commander are similar to those of signal and radio officers functioning under a Navy communication officer.

Operational Traffic

Messages pertaining to operations must be delivered promptly. The Air Force establishes direct circuits—apart from "common user" administrative circuits—for such traffic. Direct operational circuits may be by voice or teletypewriter or both, depending upon the particular situation. To get the maximum use from them, the normal practice is to provide such circuits with automatic cryptographic equipment, associated directly with the circuits, thus speeding up their use and maintaining necessary security.

When an Air Force headquarters is set up to handle operational traffic, the communication center and the operations room are in the same building. One copy of all incoming operational traffic is passed immediately to the operations room. (Recording, duplicating, and headquarters distribution are secondary to this primary requirement.) Outgoing traffic is passed directly from the operations room to the communication center for immediate transmission.

COAST GUARD

During World Wars I and II, the Coast Guard functioned as a component of the Navy, and adhered to the communication doctrine set forth in *U. S. Navy Communication Instructions*. Since the war, this agency has

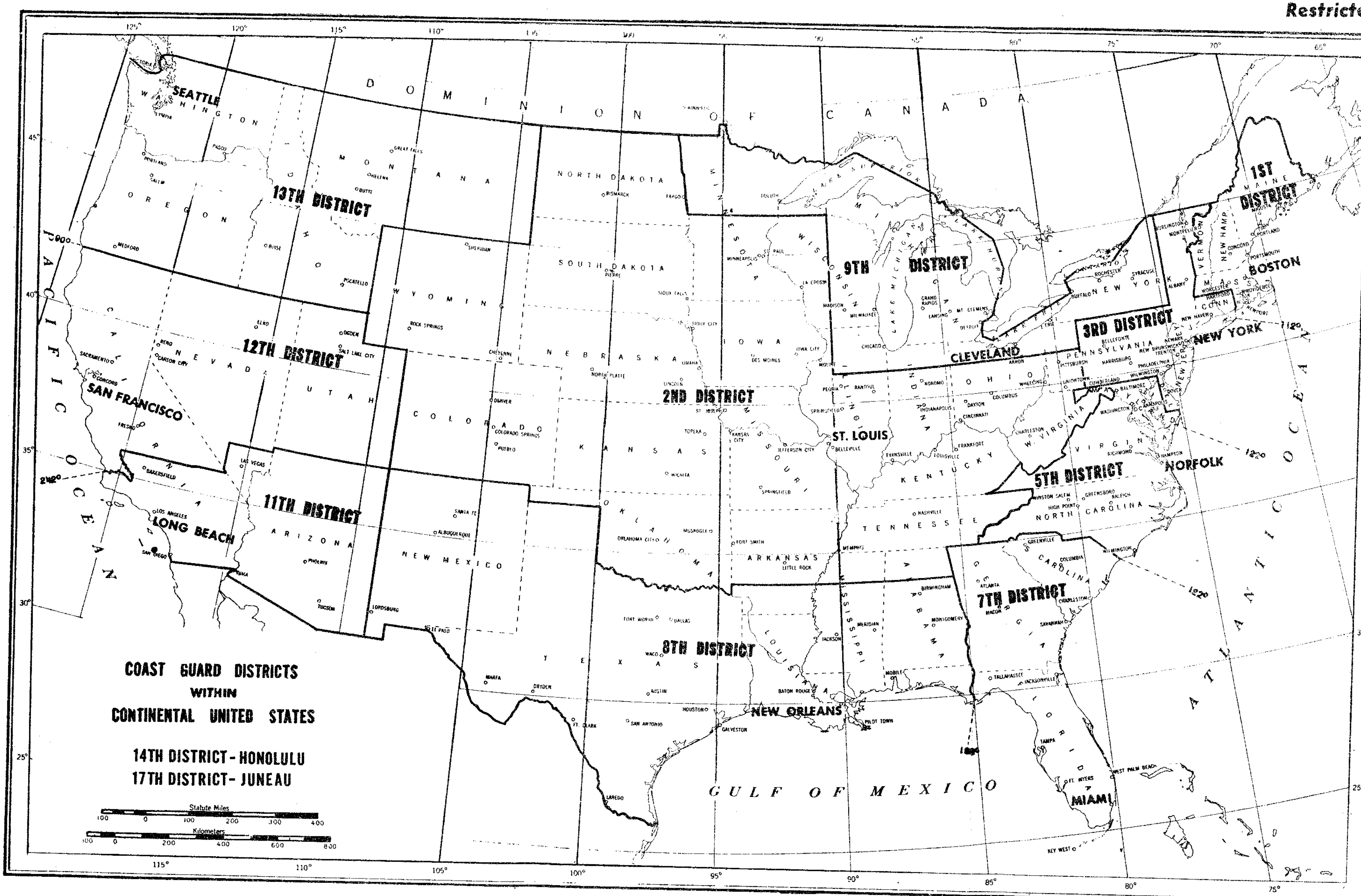

Figure 4.—Coast Guard districts.

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resumed operations under the Treasury Department, but with Joint communications now a reality, communication procedures of the Coast Guard are the same as those of the Navy, Army, and Air Force.

The Coast Guard combines the former Revenue Cutter Service, the Lifesaving Service, and the Lighthouse Service. The duties and responsibilities of this agency include enforcement of Federal laws of the United States, saving and protection of life and property, and participation in the national defense, as necessary. As the name implies, much of the Coast Guard's work is done in United States coastal waters. As a result, this agency does not require as great or extensive a communication system as the Navy.

There are 11 Coast Guard districts (fig. 4). These districts are numbered from 1 to 14, omitting 4, 6, and 10, since there are no districts with these numbers. The commandant of each district is responsible for communications within the district. Communications for an area commander are furnished by the district in which he has his headquarters. This is similar to Navy communication organization. For instance, the Commander of the Eastern Sea Frontier has his headquarters in New York City, which is in the Third Naval District. Communication facilities for that commander are furnished by the Third Naval District.

Coast Guard districts are divided into an eastern area, a western area, and independent districts (2d, 9th, and 14th). Weather ships in the Atlantic operate under the 1st Coast Guard District, and weather ships in the Pacific operate under the 12th and 13th Coast Guard Districts.

Coast Guard communications between ships and shore stations are handled by the receipt (R) method. The only Fox method broadcast operated by the Coast Guard emanates from Seattle and serves North Pacific areas including Alaskan waters.

One of the principal duties of this agency is the coordination of search and rescue procedures. Lifeboat stations and lifeboats are radio equipped to provide necessary communications, and distress frequencies are constantly guarded. Where commercial facilities are not available, the Coast Guard maintains its own telephone lines. Up and down the coasts, lifeboat and light stations are in contact with each other by telephone network.

As an aid to navigation, the Coast Guard is responsible for maintenance and operation of loran and radio-direction-finder stations.

FEDERAL COMMUNICATIONS COMMISSION

The Federal Communications Commission is the agency charged with regulating interstate and foreign communications, including radio and wire services. It also licenses operators and non-Government radio stations.

Regulation by the FCC provides for development and operation of radio broadcasting services and makes available rapid, efficient Nation-wide and world-wide wire and radio communication service. It makes these available with adequate facilities at reasonable charges.

The FCC is not a part of any Government department. It was created by an Act of Congress (the Communications Act of 1934) and reports directly to Congress. Formerly, jurisdiction over electrical communications was shared by the Commerce Department, Post Office Department, the Interstate Commerce Commission, and later by the Federal Radio Commission. With the Communications Act, all supervisory and regulatory functions were assigned to the FCC.

The FCC is administered by seven commissioners appointed by the President and subject to confirmation by the Senate. One of the commissioners is designated chairman by the President. Not more than four commissioners may be members of the same political party.

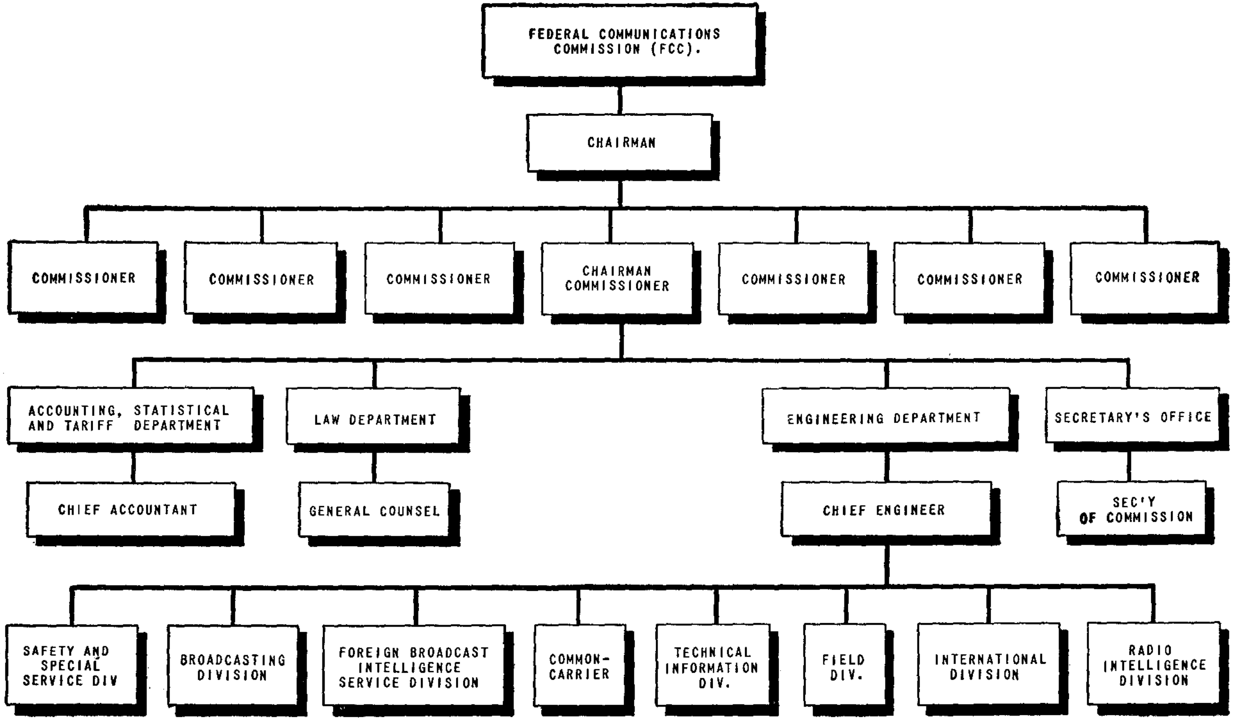


Figure 5.—Diagram of FCC organization.

Restricted

Except for filling an unexpired term, the term of a commissioner is 7 years.

In matters national and international, the FCC cooperates with various Government agencies, including State, Army, Navy, Treasury, Interior, and Commerce Departments, and other users of radio in the Federal establishment. It also cooperates with State regulatory commissions in matters of mutual interest. This is done largely through the National Association of Railroad and Utilities Commissioners.

The Communications Act applies to the 48 States, to Alaska, Hawaii, Puerto Rico, and other possessions. It does not apply to the Canal Zone. Functioning within these areas, the FCC has 23 radio district offices, 6 suboffices and 4 ship offices. There are also various monitoring stations and a field engineering laboratory. Field duties include monitoring and inspecting all classes of radio stations, examining radio operators, making various radio measurements and field intensity recordings, and conducting related investigations. In addition, there are four accounting, three law, and three common-carrier engineering field offices. (A common carrier is any person or company furnishing wire or radio communication to the public for hire, with the exception of broadcasters.) Since broadcasting stations are not deemed common carriers, the FCC does not regulate charges for program time. Even though the Commission monitors broadcasts, it has no power to censor radio programs.

Licensing

Since only a limited number of radio transmissions can be on the air at the same time without causing interference, the Communications Act requires all non-Government radio operations to be licensed. Courts have held that radio transmission anywhere within the United States or its possessions requires licensing both the transmitter and its operator.

Although FCC issues licenses to both operators and transmitting stations, the Commission collects no fee or charge of any kind in connection with this licensing. When the FCC issues a license, it first makes sure the license will serve the "public interest, convenience, and necessity." Because channels are limited and are a part of the public domain, it is important that they be entrusted to licensees who have a high sense of public responsibility. The license privilege is extended by the Communications Act only to citizens of the United States. It is denied to corporations wherein any officer or director is an alien, or of which more than one-fifth of the capital stock is owned or voted by aliens or their representatives.

Assigning Call Letters

International agreement provides for the national identification of a station by the first letter, or first two letters, of its assigned call signal, and for this purpose assigns the alphabet among the several nations. For all United States stations, except mobile stations of the Army, the Commission is authorized by the Communications Act to assign call signals. The Commission presently uses the initial letters A, K, N, and W. Except blocks of call signs assigned to particular Government agencies or departments for their own use, call signals are assigned by the Commission upon an individual-station basis. The initial letter N is generally reserved at the present time for use of the Navy and Coast Guard, whereas the letters A, K, and W are shared by other stations, both Government and non-Government. Broadcast stations are assigned call signals beginning with K or W. Generally speaking, call letters beginning with K are assigned to broadcast stations west of the Mississippi River and in the territories and possessions, while W is assigned to broadcast stations east of the Mississippi.

Policing the Ether

One of the important functions of the FCC is that of "policing the ether." This is done by field stations which monitor transmissions to see that they are in accordance with treaties, laws, and regulations. There are 10 primary monitoring stations and 12 secondary monitoring stations. If necessary, mobile equipment can trace illegal operation or sources of interference. Monitoring stations also furnish emergency directions to Government and civilian aircraft.

The Commission periodically inspects radio equipment on United States ocean vessels and on foreign ships calling at our ports. FCC ascertains that radiotelegraphy installations comply with the International Convention for the Safety of Life at Sea, and the shipboard radio requirements of the Communications Act. About 14,000 such inspections are made each year.

FCC in Wartime

During World War II, the Commission cooperated with the Army Air Forces in maintaining a constant vigil on the coasts, ready to close down radio transmissions which might furnish bearings for enemy aircraft. With the Office of Civilian Defense, it worked to guard vital communications facilities against sabotage. Also, the Board of War Communications, headed by the chairman of the FCC, coordinated communication activities for emergency purposes. The FCC established a foreign intelligence service which monitored foreign broadcasts for military and other Government agencies. Its own radio intelligence division policed the domestic ether and helped furnish bearings to our own aircraft.

In summary, the major activities of the Federal Communications Commission are:

1. Allocating frequencies for all licensed radio stations.

2. Licensing and regulating radio services and radio operators.

3. Regulating common carriers engaged in interstate and foreign communication by wire or radio.

4. Promoting safety through the use of radio on land, water, and in the air.

5. Encouraging more effective and widespread use of radio.

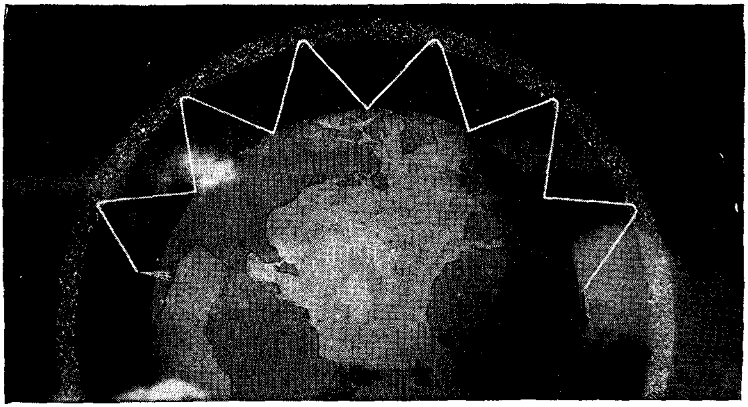
6. Utilizing its regulatory powers over wire and radio communications to aid the military effort.

For information concerning commercial traffic on Navy networks, see chapter 12 of this manual.

QUIZ

1. What is the mission of the Naval Communication Service?
2. What is meant by JOINT communications?
3. Where are the five primary communication centers located? What are their call signs?
4. What is meant by NTX? TWX?
5. What agency sets the policy of Joint communications?
6. What are the three ZONES for which the Army Signal Corps must furnish communications?
7. What is ACAN?
8. What officer in the Army holds a position corresponding to that of Chief of Naval Communications?
9. What provisions does the Army make for installation of special equipments?
10. Normally, what is the smallest Army unit to which Signal Corps troops are assigned?
11. What is the principal Air Force communication network called?
12. What are the principal duties of Air Force communication unit commanders?
13. What is the most important method used by the Coast Guard for transmitting traffic between shore stations and ships?
14. Who is responsible for communications within a Coast Guard district?

15. How was the Federal Communication Commission created?
16. The FCC is made up of how many commissioners?
17. What is the FCC charge for licensing operators and transmitting stations?
18. FCC "polices the ether"—does it have authority to censor radio programs?



CHAPTER 2

RADIO WAVE PROPAGATION

COVER THE EARTH

In this chapter you will learn how radio waves spread themselves over the face of the earth, carrying messages and music from Washington to Saipan and from San Diego to Suez in less than a second.

With your own broadcast receiver, you have probably made a few observations on the behavior of radio waves. The 1,000-watt station 700 miles away may come in clearer and stronger than a 5,000-watt station only 400 miles away. You know that your receiver does not pick up stations as well in daylight as it does at night, and that you get more distance and better reception in the winter than you do in the summer. You may have observed that some places in the United States are good radio locations, while others are naturally poor places for receiving radio programs.

THE RADIO WAVE

When it leaves a vertical antenna, the radio wave resembles a huge doughnut lying on the ground, with the antenna in the hole at the center. Part of the wave moves outward in contact with the ground to form the GROUND wave, and the rest of the wave moves upward and outward to form the SKY wave. This is illustrated in figure 6.

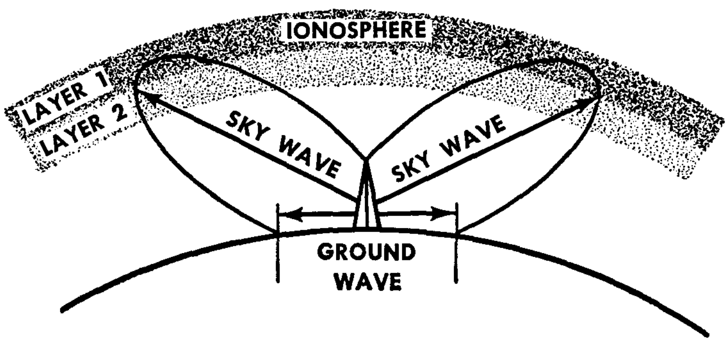


Figure 6.—Formation of the ground wave and sky wave.

The ground and sky portions of the radio wave are responsible for two different methods of carrying the messages from transmitter to receiver.

The ground wave is used for short-range communication at high frequencies with low power, and for long-range communication at low frequencies and very high power. Daytime reception from most commercial stations is carried by the ground wave.

The sky wave is used for long-range, high-frequency daylight communication. At night, the sky wave provides a means for long-range contacts at lower frequencies.

THE GROUND WAVE

The GROUND wave is made up of four parts: DIRECT, GROUND-REFLECTED, TROPOSPHERIC, and SURFACE. The relative importance and use made of each part is dependent on several factors. These factors are: frequency, distance between the transmitting and receiving antennas, height of the transmitting antenna, the nature of the ground over which the wave travels, and the condition of the atmosphere at lower levels.

The DIRECT wave travels directly from the transmitting antenna to the receiving antenna. For example, two airplanes are several thousand feet in the air and only a few miles apart. This direct wave is not influenced by the ground but may be affected by the atmospheric conditions through which the wave travels.

The GROUND-REFLECTED wave permits two airplanes several miles distant and at low altitudes to communicate with each other. The wave arrives at the receiving antenna after being reflected from the earth's surface. When the airplanes are close enough and at the correct altitude to receive both direct waves and ground-reflected waves, the signals may be either reenforced or weakened, depending upon the relative phases of the two waves.

The TROPOSPHERIC wave is the part of the wave that is subject to the influences of the atmosphere at low altitudes. The effects of the atmosphere on this type of wave propagation are most pronounced at frequencies above the high end of the HF band. Communication by use of the tropospheric wave is gaining in importance, although its range still is frequently unpredictable. This type of communication is discussed in more detail later in this chapter.

The SURFACE wave brings most of the low and medium frequency broadcasts to your receiver. These frequencies are low enough to permit this wave to follow the surface of the earth. The intensity of the surface wave decreases as it moves outward from the antenna. This ATTENUATION —rate of decrease—is influenced chiefly by the conductivity of the ground or water and the frequency of the wave.

As it passes over the ground, the surface wave induces a voltage in the earth, setting up eddy currents. The energy to create these currents is pirated or taken away from the surface wave. In this way, the surface wave is weakened as it moves away from the antenna. Increasing the frequency increases the rate of attenuation. Hence, surface wave communication is limited to the lower frequencies.

Shore establishments are able to furnish long-range ground-wave communication by using frequencies between about 18 and 300 kc. with EXTREMELY HIGH POWER.

Since the electrical properties of the earth over which the surface waves travel are relatively constant, the signal strength from a given station at a given point is nearly constant. This holds true in practically all localities, except those that have distinct rainy and dry seasons. There, the difference in the amount of moisture will cause the soil's conductivity to change.

It is interesting to note that the conductivity of salt water is 5,000 times as great as that of dry soil. The superiority of surface wave conductivity by salt water explains why high-power, low-frequency transmitters are located as close to the edge of the ocean as practicable.

Do not think that the surface wave is confined to the earth's surface only. It also extends a considerable distance up into the air, but it drops in intensity as it rises.

THE SKY WAVE

In behavior, the SKY wave is quite different from the ground wave. The part of the expanding lobe that moves toward the sky bumps into an ionized layer of atmosphere, called the ionosphere, and is bounced or bent back toward the earth. If your receiver is located in the area where the returning wave strikes, you will receive the program clearly even though you are several hundred miles beyond the range of the ground wave.

THE IONOSPHERE

The IONOSPHERE is found in the rarified atmosphere, approximately 30 to 350 miles above the earth. It differs from the atmosphere in that it contains a higher percentage of positive and negative ions.

The ions are produced by the ultraviolet and particle radiations from the sun. The rotation of the earth on its axis, the annual course of the earth around the sun, and the development of sunspots all affect the number of ions present in the ionosphere, and this in turn affects the quality and distance of radio transmission.

You must understand that the ionosphere is constantly changing. Some of the ions are recombining to form atoms, while some atoms are being split to form ions. The rate of recombination of ions to form atoms and the breakdown of atoms into ions depends upon the amount of air present, and the strength of the sun's radiations.

At altitudes above 350 miles, the particles of air are too sparse to permit large-scale ion formation. At about 30 miles altitude, few ions are present because the rate of recombination is too high. Also few ions are formed, because the sun's radiations have been materially weakened by their passage through the upper layers of the ionosphere with the result that below 30 miles too few ions exist to affect materially sky-wave communication.

Layers of the Ionosphere

Different densities of ionization make the ionosphere appear to have layers. Actually there is no sharp dividing line between layers. But for the purpose of discussion a sharp demarcation is indicated.

The ionized atmosphere at an altitude of between 30 and 55 miles is designated as the *D*-layer. Its ionization is low and has little effect on the propagation of radio waves except for the absorption of energy from the radio waves as they pass through it. The *D*-layer is present

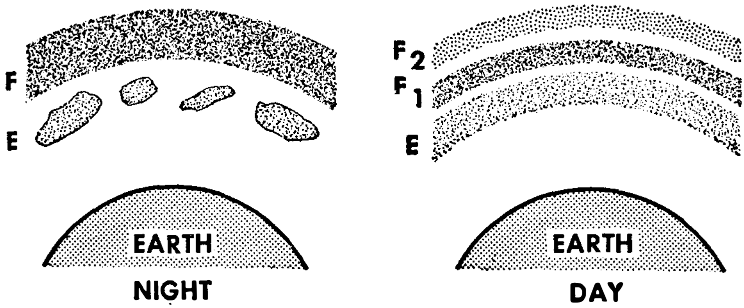


Figure 7.—E-layer and F-layer of the ionosphere.

only during the day. This greatly reduces the field intensities of transmissions that must pass through daylight zones.

The band of atmosphere at altitudes between 55 and 90 miles contains the *E*-layer. It is a well-defined band with greatest density at an altitude of about 70 miles. This layer is present during the daylight hours, and is also present in patches, called SPORADIC-*E*, both day and night. The maximum density of the regular *E*-layer appears at about noon, local time.

The ionization of the *E*-layer is sufficiently intense during the middle of the day to refract frequencies up to 20 mc. back to the earth. This is of great importance to daylight transmissions for distances up to 1,500 miles.

The *F*-layer extends from the 90-mile level to the upper limits of the ionosphere. At night only one *F*-layer is present. During the day, especially when the sun is high, this layer separates into two parts, F_1 and F_2, as illustrated in figure 7.

As a rule, the F_2-layer is at its greatest density during early afternoon hours. But there are many notable exceptions of maximum F'_2 density existing several hours later. Shortly after sunset, the F_1 and F_2-layers recombine into a single F-layer.

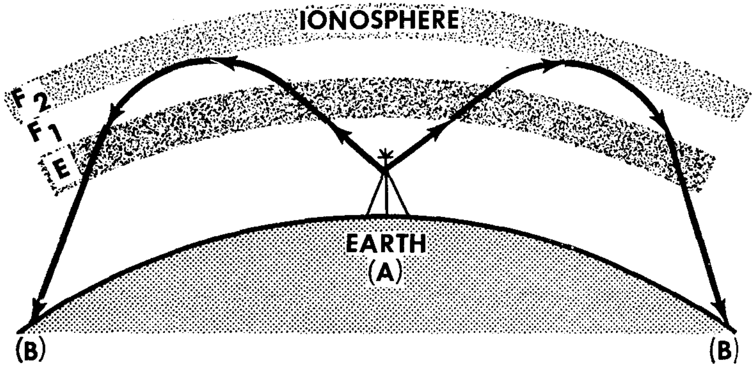


Figure 8.—Refraction of the sky wave by the ionosphere.

Sporadic E-layer

In addition to the layers of ionized atmosphere that appear regularly, erratic patches occur at E-layer heights much as clouds appear in the sky. These clouds are referred to as SPORADIC-E IONIZATIONS. These patches often are present in sufficient number and intensity to permit good radio transmission over distances not normally possible.

Sometimes sporadic ionizations appear in considerable strength at varying altitudes, and actually prove harmful to radio transmissions.

Effect of Ionosphere on the Sky Wave

The ionosphere has three effects on the sky wave. It acts as a CONDUCTOR, it ABSORBS energy from the wave, and it REFRACTS (or bends) the sky wave back to the earth, as illustrated in figure 8.

When the wave from an antenna strikes the ionosphere, the wave begins to bend. If the frequency is correct, and the ionosphere sufficiently dense, the wave will eventually emerge from the ionosphere and return to the earth. If your receiver, tuned to the same fre-

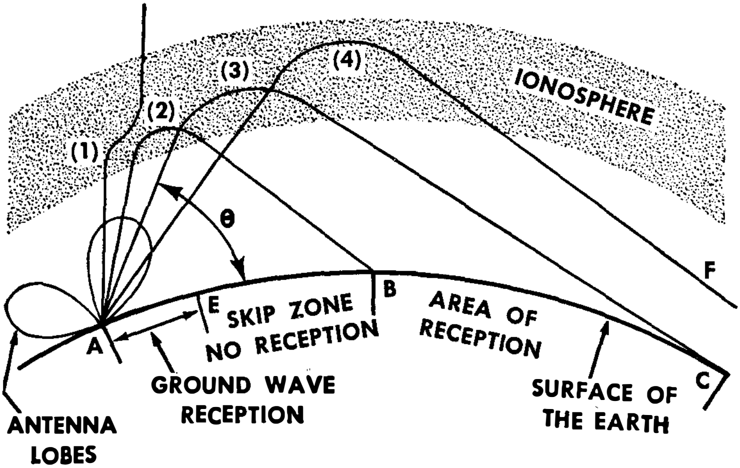


Figure 9.—Effect of angle of refraction on sky wave.

quency, is located at either of the points *B*, in figure 8, you will receive the transmission from point *A*. (Don't think that the antenna reaches as near the ionosphere as is indicated in figure 8. Remember, the tallest antenna is only about 1,000 feet high.)

The ability of the ionosphere to return a radio wave to the earth depends upon the ANGLE at which the sky wave strikes the ionosphere and upon the FREQUENCY of the transmission.

For discussion, the sky wave in figure 9 is assumed to be composed of four rays. The angle at which ray 1 strikes the ionosphere is too nearly vertical for the ray to be returned to the earth. The ray is bent out of line, but it passes through the ionosphere and is lost.

The angle made by ray 2 is called the CRITICAL ANGLE for that frequency. Any ray that leaves the antenna at an angle GREATER than Theta (Θ) will penetrate the ionosphere.

Ray 3 strikes the ionosphere at the SMALLEST ANGLE that will be refracted and still return to the earth. Any smaller angle, like ray 4, will be refracted toward the earth, but will miss it completely.

As the frequency increases, the size of the critical angle decreases. Low frequency fields can be projected straight upward and still be returned to the earth. The highest frequency that can be sent directly upward and still be returned to the earth is called the CRITICAL FREQUENCY. At sufficiently high frequencies, the wave will not be returned to the earth, regardless of the angle at which the ray strikes the ionosphere.

The critical frequency is not constant. It varies from one locality to another, according to the time of day, season of the year, and the sunspot cycle.

This variation in critical frequency is the reason you should use issued predictions—frequency tables or nomograms—to determine the MAXIMUM USABLE FREQUENCY (MUF) for any hour of the day.

Nomograms and frequency tables are prepared from experimental data obtained from stations all over the world. This information is pooled and results in long-range predictions which remove most of the guesswork from radio communication.

Refer again to figure 9. The area between points *B* and *C* will receive the transmission via the refracted sky wave. The area between points *A* and *E* will receive its signals by ground wave. All receivers located in the SKIP ZONE between points *E* and *B* will receive no transmissions from point *A*, since neither the sky wave nor the ground wave reaches this area.

Effect of Daylight on Wave Propagation

The increased ionization during the day is responsible for several important changes in sky-wave transmission:

1. It causes the sky wave to be returned to the earth nearer to the point of transmission.

2. The extra ionization increases the absorption of energy from the sky wave. If the wave travels a sufficient distance into the ionosphere, it will lose all its energy.

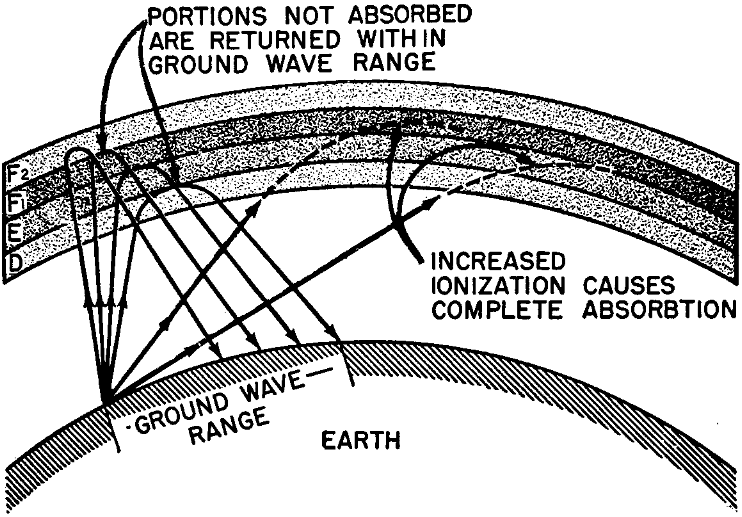


Figure 10.—Effect of daylight on medium frequency sky-wave transmission.

3. The presence of the F_1- and E-layers with the F_2-layer makes long-range, high-frequency communication possible by all three layers, provided the correct frequencies are used.

In figure 10, you see the results of daylight in increasing refraction and absorption. These two factors usually combine to reduce the effective daylight communication range of low-frequency and medium-frequency transmitters to surface wave ranges.

HIGH-FREQUENCY, LONG-RANGE COMMUNICATION

The high ionization of the F_2-layer during the day, enabling refraction of high frequencies which are not greatly absorbed, has an important effect on transmissions of the HF band. Figure 11 shows how the F_2-layer completes the refraction and returns transmissions of

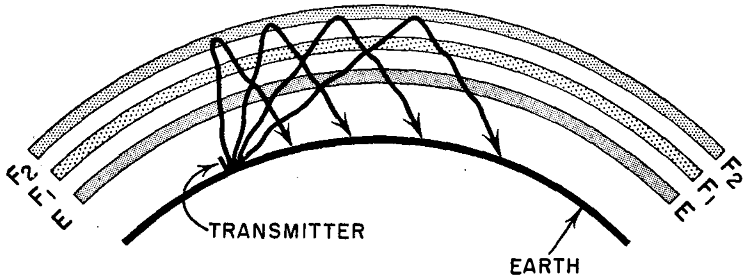


Figure 11.—Effect of the F_2-layer on transmission of high frequency signals.

these frequencies to the earth, making long-range, high-frequency communication possible during the daylight hours.

The waves are partially bent when passing through the E-layer and F_1-layer, but are not returned to the earth until the F_2-layer completes the refraction. At night, when only one layer is present, very high frequency waves may pass right through the ionosphere.

The exact frequency to be used to communicate with another station depends upon the condition of the ionosphere and upon the distance between stations. Since the ionosphere is constantly changing, you must use the nomograms and tables to pick the correct frequency for desired distance at a given time of day.

MULTIPLE REFRACTION

Many times the refracted wave will return to the earth with enough energy to be bounced back to the ionosphere, and then be refracted back to the earth a second time.

In figure 12, the ray strikes the earth at point *A* with sufficient force to be reflected back to the ionosphere and then refracted back to earth a second time. Occasionally a sky wave has sufficient energy to be refracted and

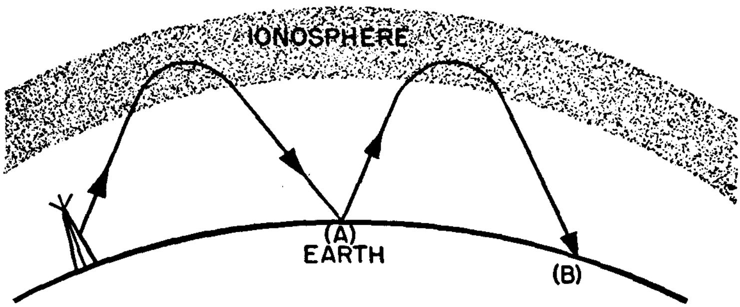


Figure 12.—Multiple refraction and reflection of a sky wave.

reflected several times, thus greatly increasing the range of transmission.

FADING

FADING is the result of variations in signal strength at the receiver. There are several causes. Some are easily understood, others are more complicated.

One cause is probably the direct result of interference between single-hop and double-hop transmission. If the two waves arrive in phase, the signal strength will be increased, but if the phases are opposed, they will cancel each other and weaken the signal.

Interference fading is also severe in regions where the ground wave and the sky wave are in contact with each other. This is especially true if the two are approximately of equal strength. Fluctuations of the sky wave with a steady ground wave can cause worse fading than sky-wave transmission alone.

The way the waves strike the antenna and the variations in absorption in the ionosphere are also responsible for fading. Occasionally, sudden ionospheric disturbances will cause complete absorption of all sky-wave radiations.

Receivers that are located near the outer edge of the skip zone are subjected to fading as the sky wave alternately strikes and skips over the area. This type of fading is sometimes so complete that the signal strength may fall too near zero level.

FREQUENCY BLACKOUTS

FREQUENCY BLACKOUTS are closely related to some types of fading, but this fading is complete enough to blot out the transmission completely.

Changing conditions in the ionosphere shortly before sunrise and after sunset may cause complete blackouts at certain frequencies. The HIGHER frequencies pass through the ionosphere, while the LOWER ones are absorbed by it.

IONOSPHERIC STORMS are turbulent conditions in the ionosphere which often cause communications to be erratic. Some frequencies will be completely blotted out, while others may be reenforced. Sometimes these storms develop in a few minutes; at other times they take several hours to develop. A storm may last several days. You can expect these storms to recur about every 27 days.

When frequency blackouts occur, you will have to be on the ball to prevent complete loss of contact with other ships or stations. When the storms are severe, the critical frequencies are much lower, and the absorption in the lower layers of the ionosphere is much higher.

VHF AND UHF COMMUNICATION

In recent years there has been a trend toward the use of frequencies above 30 mc. for short range ship-to-ship and ship-to-plane communications.

Early concepts assumed that these transmissions traveled in straight lines. This naturally led to the assumption that the VHF transmitter and receiver had to be within "line-of-sight" of each other to supply radio contact.

Extensive use and additional research has shown the early line-of-sight theory to be in error because many radio waves of these frequencies are refracted. The transmitter does not have to be in sight of the receiver.

This type communication is still called LINE-OF-SIGHT TRANSMISSION. But it is better to call it VHF and UHF transmission.

It is true that UHF and VHF waves follow approximately straight lines, and large hills or mountains cast a radio shadow over areas in much the same way as light creates a shadow. A receiver located in shadow will receive a weak signal, and in some cases, no signal at all.

Theoretically, the range of contact is the distance to the horizon, and this distance is determined by the heights of the two antennas. Communication is often possible many miles beyond the assumed horizon range. Be sure to remember this point when your ship is in waters where radio security is essential.

Effect of Atmosphere on VHF and UHF Transmissions

The abnormal ranges of VHF and UHF contacts are caused by abnormal atmospheric conditions within a few miles of the earth. Normally, you will find the warmest air near the surface of the water. The air gradually becomes cooler as you gain altitude. However, unnatural situations often develop where warm masses of air are above the cooler layers. This unusual situation is called a TEMPERATURE INVERSION.

Whenever temperature inversions are present, the amount of refraction—called INDEX OF REFRACTION—is different for the air trapped within the inversion than it is for the air outside.

The differences in the index of refraction form channels or ducts that will pipe VHF and UHF signals many miles beyond the assumed normal range.

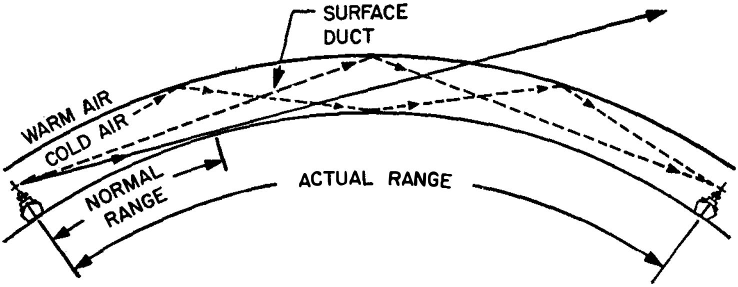


Figure 13.—Duct effect on VHF and UHF transmissions.

Sometimes these ducts will be in contact with the water and may extend a few hundred feet into the air. At other times the duct will start at an elevation of about 500 to 1,000 feet, and extend an additional 500 to 1,000 feet in the air.

If an antenna extends into the duct or if wave motion lets the wave enter a duct after leaving an antenna, the transmission may be conducted long distances to another ship whose antenna extends into the duct. This is illustrated in figure 13.

When Ducts Will Be Formed

When operating high-frequency equipment, you must be able to recognize the weather conditions that lead to duct formations. Since the duct is not visible to the eye and since complete aerological information is not always available, you must rely on available evidence and a lot of common sense.

The following rules have exceptions, but you can expect a duct to be formed when:

1. A wind is blowing from land.
2. There is a stratum of quiet air.

3. There are clear skies, little wind, and high barometric conditions.

4. A cool breeze is blowing over warm open ocean, especially in the tropic areas and in the trade-wind belt.

5. Smoke, haze, or dust fails to rise, but spreads out horizontally.

6. Your receiver is fading rapidly.

7. The moisture content of the air at the bridge is considerably less than at the ocean surface.

8. The temperature at the bridge is 1° or 2° F. higher than at the ocean surface.

General Use of Frequencies

Each frequency band has its own special uses. These uses depend upon the nature of the waves—surface, sky, or space—and the effect that sun, earth, ionosphere, and atmosphere have upon them.

It is almost impossible to lay down fixed rules for the use of different frequencies for different purposes. However, some general statements can be made. JCI lists each frequency band and its best use.

Most rules for the use of frequencies deal with VARIATIONS that are beyond human control. This is particularly true of medium- and high-frequency transmissions using the sky wave. Your best bet is to make intelligent use of nomograms and frequency tables.

One way of being reasonably certain that a LONG-RANGE COMMUNICATION will get through is to use HIGH POWER and LOW FREQUENCY. That's what the international communication systems and most big Fox stations use. However, this takes an antenna array so large that it's not usable with shipboard transmission. So, to be certain a message for a distant point gets through, RELAY IT—send it to the nearest large shore station.

Note in figure 14 how the sky wave builds up to a peak of daytime usefulness in the HF band. At night the peak is in the top third of the MF band. Note also how the usefulness of the GROUND (or surface) wave declines steadily as the higher frequencies are reached, until it is altogether useless in HF. But as the SPACE wave it becomes the only means of communication in VLF and for a certain range above VLF.

Remember that all sky-wave transmission—and that means almost all from 1600 to 30000 kc.—is associated with SKIP DISTANCES. In other words, you can get great range but in the process you'll skip a lot of receiving stations in between—possibly the one you wish to receive your message.

THE NAVY FREQUENCY BAND

Most important to you in the chart is the shaded area in the MF and HF bands—from 2000 to 18100 kc. (2 to 18.1 mc.). This is the standard band for naval communications from ship-to-ship and ship-to-shore. It's the band you'll use most frequently for TRANSMITTING messages, the one which your standard transmitters, such as the TBK, TBL, and TBM, cover.

It's in the short-wave area. Therefore, it's sky-wave transmission and is affected by skip distances. As the chart shows, when you want range in DAYTIME, use the UPPER PORTION of the band, from 3 mc. to 18 mc. For NIGHT communication, the lower end of the band is usually used. The three frequencies most commonly used in this band are 2716 kc. (2.716 mc.), 2844 kc. (2.844 mc.), and 4235 kc. (4.235 mc.) the NERK series.

To help you use this band, and to explain skip distance more thoroughly, the Navy publishes NRPM's containing tables which show the best frequencies for communication with various shore stations. These tables are issued quarterly. There will be a separate one for each major shore station, giving the recommended frequency for every hour of day for every distance. The direction of the receiving station from your ship is also taken into account.

FREQUENCY		RANGE OF TRANSMISSION			
SYMBOL	KCS (OR MCS)	DAYTIME		NIGHTIME	
		SKY WAVE	GROUND WAVE	SKY WAVE	GROUND WAVE
VLF	BELOW 30 KC	NONE	LONG RANGE WHEN VERY HIGH POWER USED	NONE	SAME AS DAY
LF	30-300 KC	NONE	SIMILAR VLF BUT SOMEWHAT LESS EFFECTIVE	LIMITED AT UPPER END OF BAND	SAME AS DAY
MF	300-550 KC	NONE	MAXIMUM FEW HUNDRED MILES	EFFECTIVE-DEPENDS ON SKIP DISTANCES	SOME
	550-1600 KC (BROADCAST)	NONE	MAXIMUM FEW HUNDRED MILES	EFFECTIVE-DEPENDS ON SKIP DISTANCES	SOME
	1600-3000 KC (INTERNATIONAL "SHORT WAVE")	SOME	LIMITED	LONG RANGE-DEPENDS ON SKIP DISTANCES	VERY LITTLE
			STANDARD NAVAL BAND - 2 TO 18 MC		
HF	3-30 MC (INTERNATIONAL "SHORT WAVE")	LONG RANGE-DEPENDS ON SKIP DISTANCES	LIMITED	USUALLY NONE	USUALLY NONE
VHF	30-300 MC	NONE	TROPOSPHERIC WAVE	NONE	TROPOSPHERIC WAVE
UHF	300-3000 MC				
SHF	3000-30,000 MC				

Figure 14.—Recommended frequency chart.

Look at the table in figure 14. It's for communication with Balboa during February 1949. Your ship is 750 miles off the Pacific coast of Central America during that February, the time is 1200 GCT, and you wish to get a message to NBA, Balboa. Look at your table for the proper time, then move over to the third column—500 to 1,000 miles—in the second vertical row of figures, since Balboa is east of you. The recommended frequency in 4 mc. Send your message on that frequency.

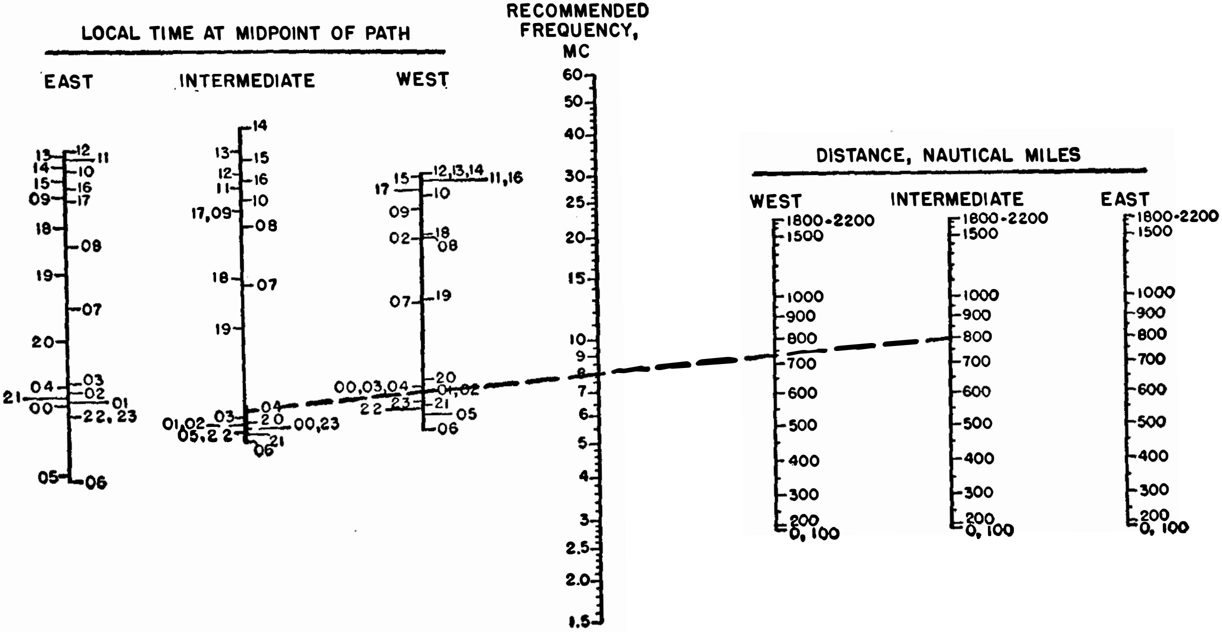
These tables will be supplied to your ship in the form of NRPM's and will cover 3-month periods, with a separate table for each month and for each shore station.

NOMOGRAMS

As an additional aid, you'll be supplied with NOMOGRAMS—again in NRPM's. They cover 3-month periods, and each nomogram covers a range of 10° in latitude. A nomogram may be used for any path where the midpoint lies within the range of latitude of the particular nomogram. It will give you the proper frequency for any time of day in Local Civil Time (LCT) for any transmission from 1 to 2,200 miles. With proper use of nomograms and the frequency tables you should be all set for communicating in the Navy HF band.

Figure 15 shows a nomogram that is typical of the series you'll use most frequently. To use, first locate the approximate midpoint of the transmission path on the map shown on the last page of each published nomogram series. Determine the latitude, local time, and the zone at this midpoint. (Zones are labeled E, W, and I on the map to represent East, West, and Intermediate.) Then line up a ruler through the distance of transmission (right hand column) and the local time (LCT) at the midpoint of the path on the left-hand column. Where the straight edge intersects the frequency scale in the middle of the nomogram, you'll find the recommended frequency.

Suppose you want to make a transmission of 800 nau-



LATITUDE 30° N. PREDICTED FOR FEBRUARY, 1949

Figure 15.—Nomograms.

tical miles at 0400. You have consulted the map and found that the midpoint of the path is at roughly 30° north latitude and lies in the I (Intermediate) zone. Local time at this point is approximately the same (0400). Line up your straight edge on the nomogram in figure 15 between the Intermediate zone MILES line on the right side and the Intermediate zone TIME line on the left. Then look at your recommended frequency column in the middle. You will see that it is intersected at 8 mc. by the diagonal line made by the ruler. Your frequency is 8 mc. Working the beach on the ship-shore circuit, you would therefore use 8470 kcs.

But There Are Others

The so-called Navy band is not the only one used. It's the standard ship long-distance communications frequency—your chief transmitting frequency.

In transmitting Fleet Broadcast Schedules from the Primary Communication Centers, one or more centrally located high-power transmitters will beam the traffic to ships at sea. The flow of traffic is assured by broadcasting simultaneously over two frequency ranges (either VLF or LF), together with as many as five HF transmissions.

To make certain that broadcasts reach fleet receivers these frequencies are manually keyed at a speed of about 18 w. p. m., never exceeding 25 w. p. m. Messages are not usually repeated, although important messages are sometimes rebroadcast on a subsequent schedule to insure reception. This does not apply to traffic for submarines, as that is almost always repeated on later schedules.

Most ships copying a Broadcast schedule will tune to a high and a low frequency, or to two high frequencies over different receivers; one to be copied by the regular circuit man, and the other by a back-up man, if equipment and personnel are available. This guarantees optimum reception in the same way as does the series of diversity receivers at a major shore station.

In addition to Primary Fleet Broadcasts, the Primary Communication Centers maintain Primary General Broadcasts, the characteristics of which are similar to the Primary Broadcasts. These broadcasts carry the following services: time signals, weather reports, hydrographic warnings, notices to mariners, merchant ship traffic, and some press stories.

As you go up into VHF and UHF, you enter the TACTICAL bands. When it's radiotelephone communication over the TBS or TDQ/RCK, you go up to the SPACE WAVE. And remember your range limitations.

As a final tip on the proper use of frequencies, be sure you know the proper PUBLICATIONS to use. JCI gives the shore station circuits, the FOX stations and the frequencies they use, the ship-shore facilities provided by the shore organizations, and the stations giving DF calibrating service on frequencies ranging from 150 to 1,500 kc., as well as those giving HFDF service.

The CONFIDENTIAL publication, *The U.S. Naval Radio Frequency Usage Plan,* lists all bands and what the Navy's currently using them for. There are the *IRPL Radio Propagation Handbook* (DNC13–1), effective USF–70, current NRPM's, and circular letters to turn to for further up-to-date frequency data when needed. DNC–22 gives the dope on VHF propagation.

QUIZ

1. What determines the exact frequency to be used to communicate with another station?
2. What is known as the standard band for Naval communications?
3. What three effects does the ionosphere have on the sky wave?
4. In what part of the day is the D-layer present?
5. What are the four parts that make up a ground wave?

6. The ionosphere is located approximately how many miles above the earth?
7. Of what use is the sky wave at night?
8. What is the conductivity of salt water in comparison to dry soil?
9. Is the surface wave confined to the earth's surface only?
10. What is meant by critical frequency?

CHAPTER 3

ANTENNAS

RADIATING ENERGY

An antenna, as you already know, is a piece of wire cut to the proper length and correctly installed so that it will efficiently radiate all the energy produced by the transmitter. The word EFFICIENTLY is the word you want to remember. Any wire carrying alternating current radiates electromagnetic energy—remember the hum that your receiver picked up from a 60-cycle power line, and the static from a neon sign driven by an induction coil?

The power line and neon signs are not efficient radiators because they were not designed as radiators. The power line carries energy from the power plant to its destination, while a neon sign is built to produce light.

But an antenna IS designed to radiate, in the form of electromagnetic waves, all the energy delivered to it by the transmitter, As you read further in this chapter you will find repeated some of the material you studied in the Radioman 3 and 2 training course. A little review is necessary at this point so that you can continue your study of antennas with all the fundamentals clearly in mind.

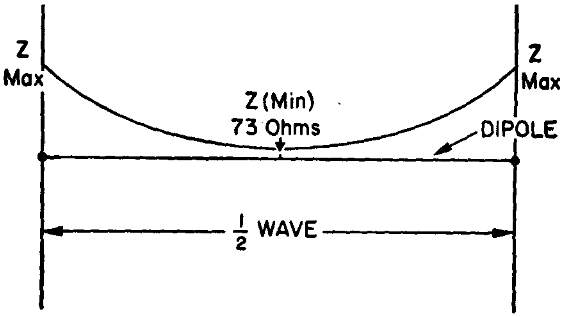


Figure 16.—Impedance in a dipole.

THE DIPOLE

The basic antenna is a dipole—wire with a length equal to half a wave length.

If a station is operating on a wave length of 100 meters, the dipole length will be—

$$\frac{100}{2} = 50 \text{ meters, or about 164 feet.}$$

A transmitter operating on a wave length of one meter (300 mc.) will require a dipole one-half meter long—about 20 inches.

IMPEDANCE OF A DIPOLE

First of all, you must remember that an antenna carries alternating current. Therefore the antenna will have inductive reactance, as well as resistance. Reactance plus resistance make up the impedance of the antenna.

Suppose a dipole is suspended in space between two perfect insulators. Where will the impedance be the greatest along the wire? Since the perfect insulator has a resistance of infinity—extremely great—the R in the equation $Z = \sqrt{R^2 + X_L^2}$ plus the inductance will cause the Z to become greatest at the ends.

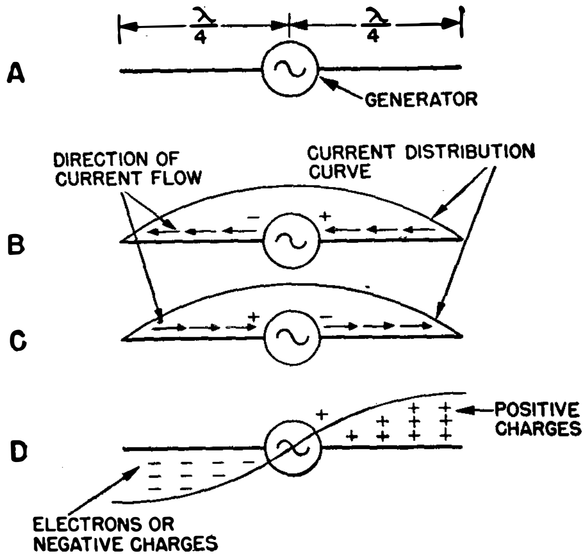


Figure 17.—Development of an antenna.

If the impedance is maximum at both ends, it is logical that the impedance is minimum at the center of the dipole. In figure 16, the impedance is shown to be the greatest at each end, gradually diminishing until it reaches minimum at the center.

The impedance, or radiation resistance of a dipole at its center, is approximately 73.2 ohms, regardless of what frequency you use.

CURRENT AND VOLTAGE IN A HALF-WAVE ANTENNA

If a feeder line from the transmitter is connected to the center of a dipole, the antenna will operate as if you had set an a. c. generator between two quarter-wave antennas. (See fig. 17a.)

During half the alternation, the electrons will flow from right to left (fig. 17b). On the next half alternation, the generator will make the electrons flow in the opposite direction (fig. 17c).

In an antenna, as in any other circuit, the flow of electrons is the greatest where the impedance is least. Therefore, more electrons will be moving at the center of the dipole than at the ends.

Where's the voltage along the antenna? Voltage is always greatest where the impedance is the highest. Thus, you will find the highest voltage at the ends of the dipole (fig. 17d). During half an alternation, the left end of the dipole will be maximum negative, and the right end will be positive. On the next half alternation the polarity of the voltage is reversed.

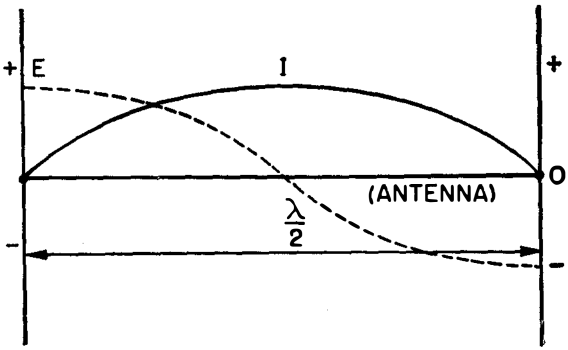


Figure 18.—Relationship of current and voltage in a dipole.

If the antenna extends exactly a quarter-wave length on each side of the generator, the rebounding or reflected electrons from the negative end of the dipole will return at the proper instant to reinforce the movement of other electrons already moving in that direction. But if the antenna is greater or less than a quarter-wave length on each side of the generation, much of the energy will be lost in the collision of the electrons trying to flow in two directions at the same time. From this you can see the importance of cutting the antenna the proper length.

From the current-voltage diagrams of figure 18, you can see the characteristics of an antenna. The current is maximum at the center, and the voltage is maximum positive at one end and maximum negative at the other end.

ELECTROMAGNETIC FIELD SURROUNDING A DIPOLE

A dipole suspended in space away from the influence of the earth will be surrounded by an electromagnetic field the shape of a doughnut, as shown in figure 19a.

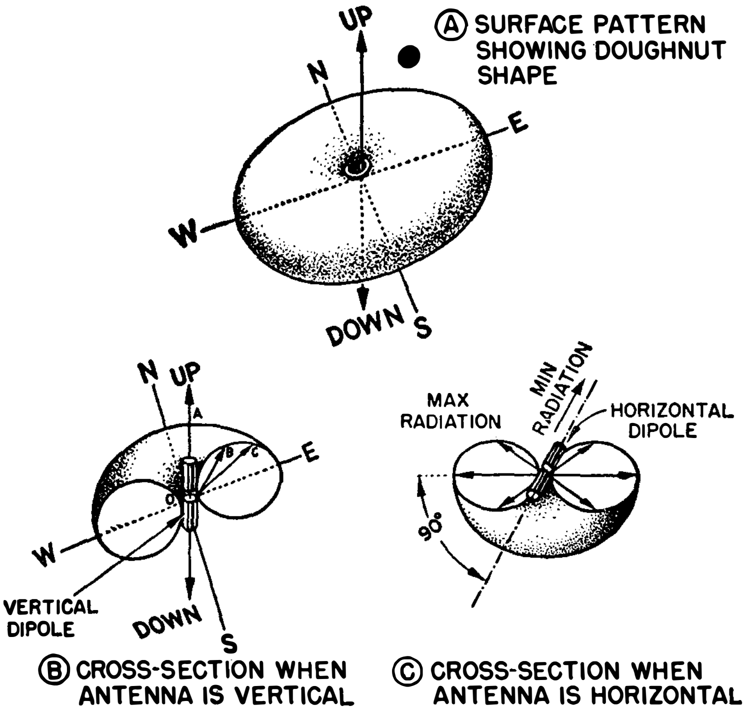


Figure 19.—Electromagnetic field surrounding a dipole.

You can see that no radiation takes place at the ends of the dipole. If the antenna is mounted vertically, the field will have the shape of a doughnut lying on the ground. All areas surrounding the dipole will receive a magnetic field of equal strength, as in figure 19b.

Set the dipole parallel to the surface of the earth, and the field is the shape of a doughnut standing on edge. The greatest field strength will be along a vertical line perpendicular to the dipole.

ELECTROSTATIC FIELD SURROUNDING A DIPOLE

High voltages at each end of the dipole produce an electrostatic field which is at maximum strength at the ends of the dipole. But if the antenna is shorter or longer than half a wave length, the electrostatic field strength will be greatest at the point where the voltage is maximum.

STANDING WAVES

The electrostatic and electromagnetic field surrounding an antenna each form individual standing waves. The two

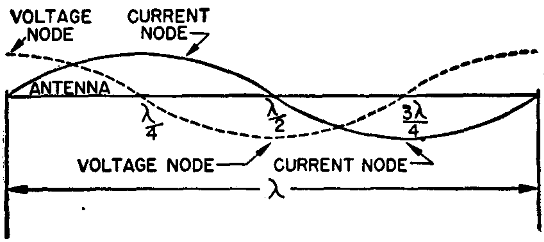


Figure 20.—Standing waves along full-wave antenna.

types of standing waves are as dissimilar as current and voltage. The electrostatic field is 90° out of phase with the electromagnetic field. The presence of an electromagnetic field can be shown by the glowing of an incandescent lamp-loop in the presence of the field, while a neon lamp will glow in the presence of an electrostatic field. The points along an antenna where the magnetic fields are maximum are called current loops. The points where the electrostatic fields are maximum are called voltage loops.

Figure 20 shows the location of the loop points along a full-wave antenna. The current loops appear every half wave length, and the voltage loops appear every other half-wave length.

If you move a neon bulb along an r. f. transmission line, the bulb will glow each time a voltage loop is reached. If the transmission line is several wave lengths long, several voltage loops will be spotted.

You can determine the wave length of your antenna by measuring the distance between the loop points, since each loop is exactly one-half wave length from the others.

ELECTRICAL LENGTH AND ACTUAL LENGTH OF ANTENNA

An ideal antenna, one completely free from the influence of the earth, would have an actual length exactly equal to its electrical length. For instance, an ideal half-wave antenna for use with a 100-meter wave length would be 50 meters long. But since no antenna is completely free from the influence of the earth, the physical length of an antenna is approximately 5 percent less than its electrical length. A half-wave antenna for a 100-meter station will be 50 meters less 5 percent, or 47½ meters long.

The physical length of a half-wave antenna for frequencies above 30 mc. can be calculated from the frequency by using the following equation—

$$\text{Length (feet)} = \frac{492 \times 0.95}{\text{frequency, in megacycles}}$$

The number 492 is a factor for converting meters to feet. The correction factor, 0.95, is 100 percent minus the 5 percent loss due to the effect of the earth.

THE HERTZ ANTENNA

Any antenna that is one-half wave length long is a Hertz antenna, and may be mounted either vertically or horizontally. The great length of Hertz antennas makes them difficult and costly to build, especially for handling low frequencies. Consider the problem of constructing a half-wave antenna for a wave length of 545 meters—550 kc. The antenna would have to be about 850 feet long! You can imagine the weight of a horizontal span of cable 850 feet long. And a vertical half-wave antenna would be as tall as the RCA Building in New York's Radio City.

Because of the construction difficulties and costs, you will seldom find half-wave antennas used with broadcasting transmitters operating at frequencies below 1,000 kc. But half-wave antennas are widely used with high-frequency communication transmitters. A half-wave antenna for a 30 mc.—10 meter—transmitter will be only a little over 16 feet long.

THE MARCONI ANTENNA

The Marconi antenna is also known as the quarter-wave or grounded antenna.

Figure 21 illustrates the principle of a Marconi antenna mounted on the surface of the earth. The transmitter is connected between the bottom of the antenna and the earth.

Although the antenna is only a quarter-wave length, the reflection of image in the earth is equivalent to another quarter-wave antenna. By this arrangement, half-wave operation can be obtained from an antenna only a quarter wave length long.

The relationships of impedance, current, and voltage in a quarter-wave grounded antenna are similar to those in a half-wave Hertz antenna. Impedance and voltage are maximum at the top of the antenna and minimum at the bottom. The flow of current is greatest at the bottom and least at the top.

The radiation resistance is used as a measure of the ability of an antenna to radiate power. An antenna with a high radiation resistance is a good radiator, and vice versa.

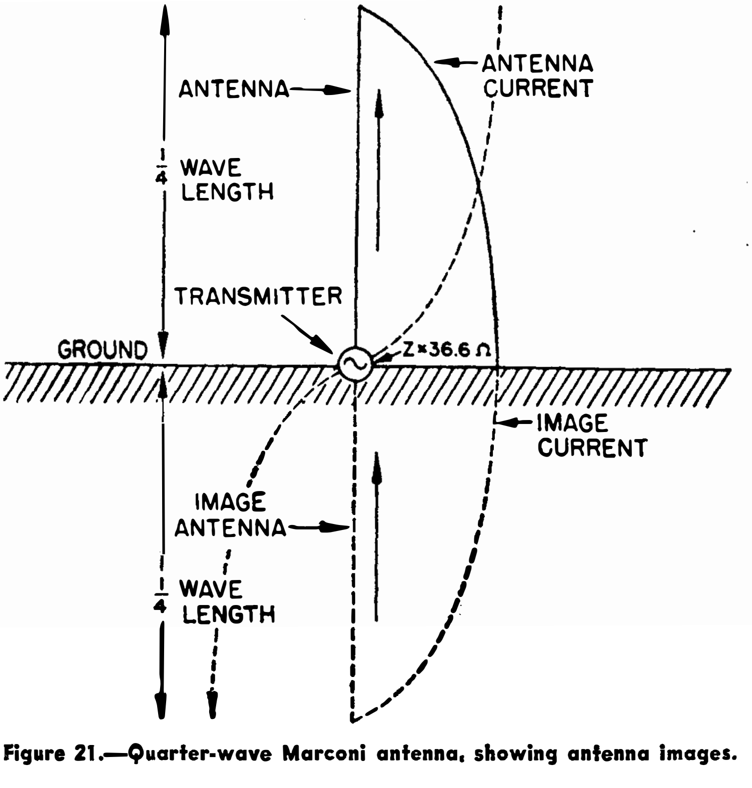


Figure 21.—Quarter-wave Marconi antenna, showing antenna images.

Loss resistance is made up of the following components:

1. *Loss due to hysteresis* caused by the presence of poor dielectrics such as trees, masts, etc. Since very high voltages are developed at the free end of an antenna, special care should be taken to keep poor dielectrics away from that part of the antenna.

2. *Loss in the ohmic resistance of the antenna,* which includes skin effects. This loss may be kept low by giving the antenna sufficient cross section and using woven or stranded wire.

3. *Loss in the resistance of the counterpoise or ground,* caused by not using a counterpoise of the smallest possible resistance. Where the ground is the counterpoise it is important that connection be made to it by a large number of copper plates or wires buried all around the antenna. Counterpoises of this type are not employed aboard ship.

4. *Loss due to eddy currents in nearby conductors* may be lessened by erecting the antenna as far as possible from masts, guys, cranes, stacks, etc.

5. *Loss due to leakage over insulators* can be minimized by using insulators of proper design and material. Insulators should be kept free from dirt, paint, or moisture. In this connection certain types of porcelain insulators that have lost their surface glaze absorb moisture and therefore make poor insulators. Wet weather increases losses due to leakage. Aboard ship, salt spray on the insulators may cause a large part of the power in the antenna to be lost.

6. *Loss due to corona* takes place at high voltages and is caused by the partial ionization of the air about the antenna wires. This causes the air to become a partial conductor and carry current. This glow is sometimes visible at night. Corona shields are installed in some of the larger insulators to reduce the voltage gradient between the ends of an antenna and the rigging. Due to corona losses the voltage at the ends of an antenna is limited to about 150,000 volts. The larger an antenna, the greater its capacity and the lower the voltage gradient across it.

Practical shipboard antennas may be roughly divided into three classifications: (1) Those that are extremely short compared to a quarter-wave length. These include the low and intermediate frequency antennas. (2) Antennas connected to transmitters through trunks where the trunk length approaches a quarter wave length. (3) Antennas which are generally operating at their fundamental wave length (or proper harmonics) and are connected to radio equipment by nonresonant transmission lines.

All ships employ antennas listed in (1) above because no ship has masts far enough apart to use an antenna a quarter wave length long for the low and some of the intermediate frequencies. For example, a Marconi antenna operating at its fundamental on 355 kc. would have to be 660 feet long. A Hertz antenna would be twice this length or 1,320 feet long. Even at 2,000 kc. a Marconi antenna would be 117 feet long. It is evident, therefore, that all shipboard antennas for the low and intermediate frequencies are short compared to a quarter wave length.

Such short antennas are characterized by certain disadvantages. First, high voltages are created along the antenna due to low antenna capacity for the frequencies at which they are operating. For this reason Corona losses definitely limit the amount of power that may be supplied to the antenna. Next, considerable losses result due to dielectric and eddy current losses because the antenna is so near (compared to the magnitude of a wave length) the structure of the ship. Another disadvantage lies in the fact that a very small radiation resistance limits the amount of power actually radiated. For the low frequencies, where the antenna is extremtly short compared to a quarter-wave length, the radiation resistance may be in the vicinity of 1 ohm or less. Such short antennas necessitate the use of considerable loading inductance in the transmitter in order to tune the antenna to resonance. This introduces dangerously high voltages in the transmitter. Also, because the loading inductance usually has a considerable amount of effective resistance, there is a large amount of power lost in the inductance because it is in series with the antenna, and the current to both is common.

The radiation resistance of a quarter-wave antenna at the point of greatest current flow is approximately 36.6 ohms or half the 73.2 ohms resistance at the center of a half-wave Hertz antenna.

The advantage of using a Marconi antenna can be seen when you compare the 444 feet for a Marconi to the 888 feet for a Hertz at 550 kc.

The quarter-wave antenna is used extensively with portable transmitters. On an airplane, a quarter-wave mast or trailing wire will be the antenna, and the fuselage will produce the image. Similar installations are made on ships. A quarter-wave mast or horizontal wire will be the antenna and the hull will provide the image.

ANTENNAS OF OTHER LENGTHS

Occasionally you'll need an antenna of some length other than a quarter- or half-wave length. Some of the usual lengths are shown in figure 22.

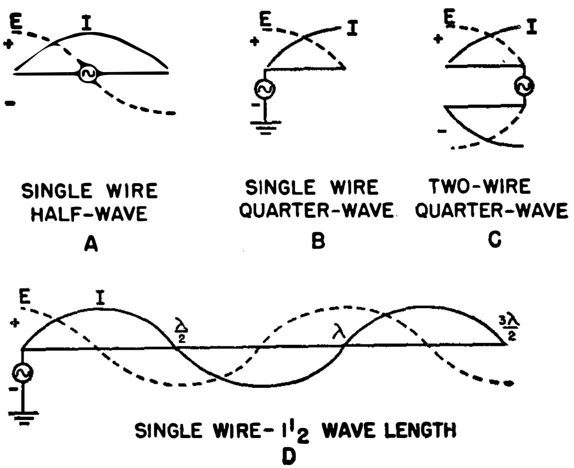


Figure 22.—Current and voltage relationships in antennas of various lengths.

Figures 22a and 22c are examples of current-fed antennas, while figures 22b and 22d are voltage-fed antennas.

The expressions voltage-fed and current-fed refer to the points along the antenna where the power is applied. In the current-fed antenna (figure 22a) the power is delivered to the antenna at the point of highest current. The antenna of figure 22b is voltage-fed—the power being applied to the point of highest voltage.

RHOMBIC

Figure 23 is the most widely used form of nonresonant antenna and made up of four nonresonant wires arranged

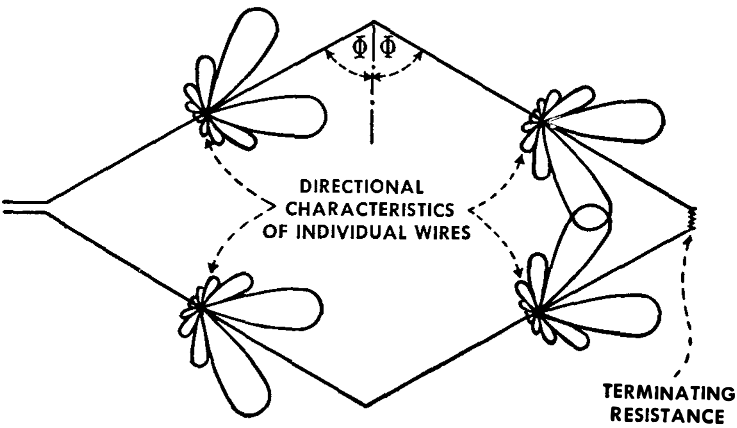


Figure 23.—Rhombic.

in the form of a diamond or rhomboid. This arrangement gives increased directivity and simplifies the terminating resistance problem because no ground connections are necessary. The terminating resistance is connected between the ends of the wires.

The Angle Θ is known as the TILT ANGLE. The value of the tilt angle is so chosen that the major lobes of the individual wires will be in the direction of a line drawn through the apexes of the antenna. They will then tend to add up in phase.

The directional characteristics of the rhombic antenna are not critical with respect to the tilt angle if it is not less than two wave lengths. As a result the rhombic antenna may be used over a fairly wide frequency range without adjustment.

When erecting a rhombic antenna it is generally the practice to make each leg about four wave lengths long for the highest frequency to be used. This arrangement gives excellent directional characteristics over a 2 to 1 frequency range.

The gain of the rhombic antenna depends on the design and the length of its legs. In practice it is possible to obtain a 20 DB gain, over the half-wave radiator. This means that if a half-wave antenna was used for reception, instead of a rhombic with a 20 DB gain, the transmitter would have to radiate 100 times more power to give the same signal strength.

CORRECT THE ELECTRICAL LENGTH

After the antenna has been erected, you may find that its physical length is greater or less than its electrical length. If a grounded antenna is less than one-quarter wave length, there will be a capacitive effect at the base, and an inductance must be added in series to increase the electrical length, as in figure 24a.

When the physical length of an antenna is greater than its correct electrical length, the antenna will have excess inductance. It will be necessary to add a condenser in series with the antenna to shorten its electrical length, as in figure 24b.

ANTENNA TUNING CIRCUITS

You will have to change the electrical length of the antenna each time you change the frequency of the transmitter. Since you can't climb up the superstructure and chop off a piece of the antenna each time you change the frequency, you will use a combination of variable inductances and condensers to adjust the electrical length. Condensers and inductances used for this purpose make up the antenna loading or antenna tuning circuits.

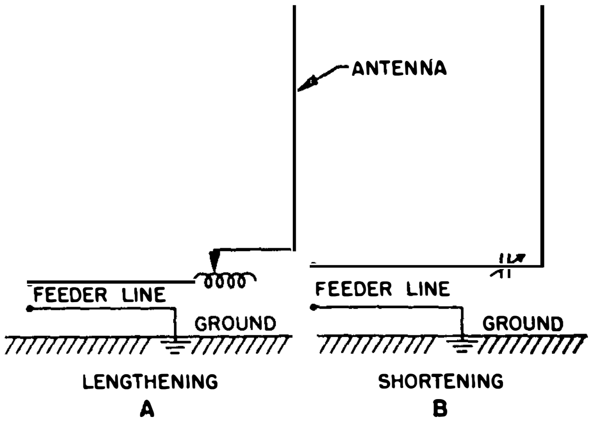


Figure 24.—Methods of correcting the electrical length of a grounded antenna.

TRANSMISSION LINES

The construction of a transmission line to carry low-frequency alternating current is relatively simple, but the building of a line that will efficiently transmit the energy of a high frequency radio transmitter to the antenna is something else!

Transmission lines used with frequencies below 300 mc. are of four general types—the open two-wire system, coaxial cable or concentric line, twisted pair and the shielded pair.

Figure 25 shows an open two-wire transmission line. Wires are held rigidly in a parallel position by insulated spacers. For 20 mc. and lower, a spacing of at least 6 inches is desirable and for frequencies higher than 20 mc. a spacing of 4 inches is best.

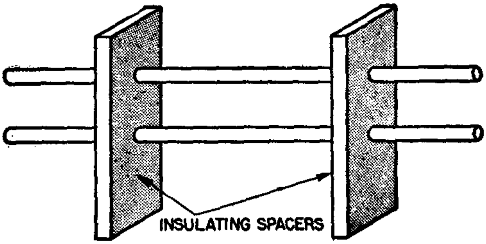


Figure 25.—Open two-wire transmission line.

Figure 26 is a drawing of a coaxial cable or concentric line. It consists of a copper tube with a copper wire extending down the length of the tube. The wire is centered in position in the tube by insulated spacers.

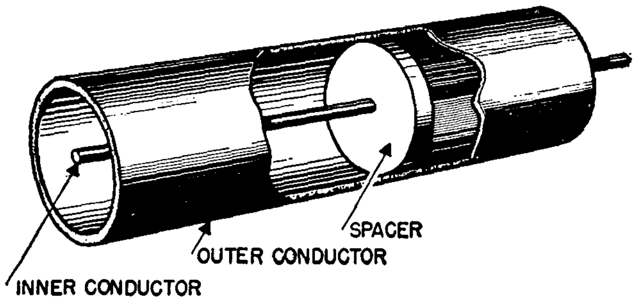


Figure 26.—Concentric line.

Higher operating efficiency is obtained by filling the tube of the concentric line with nitrogen under several pounds pressure. A pressurized line is often a source of trouble as vibrations caused by gunfire or rough sea may cause leaks which allow the pressure to drop. If this happens, the efficiency of the line will drop.

The concentric line has several advantages. The tube is grounded, allowing you to install the line in any convenient position. Because the open two-wire system lacks insulation, it must be carefully located. It is subject to stray capacitive and inductive coupling.

The pressurized concentric line will work well with frequencies up to 300 mc. Beyond that frequency, its efficiency falls off rapidly. But at 300 mc. the losses over an open two-wire system of equal length will be so great that this system is unsatisfactory.

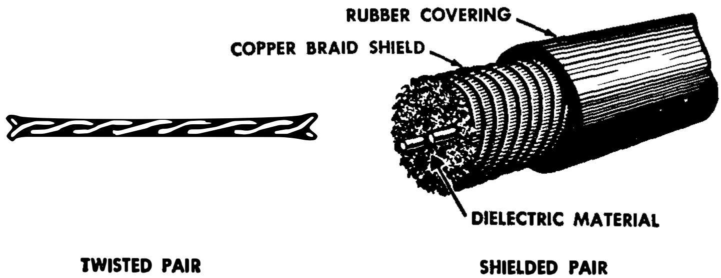


Figure 27.—Twisted-pair and shielded-pair transmission lines.

The twisted-pair and the shielded-pair are not commonly used as transmission lines. Both types are shown in figure 27. The twisted pair is the least efficient. The shielded pair possesses an advantage in having a grounded copper shield surrounding the two lines. This shield prevents any stray capacitive and inductive couplings.

RESONANT AND NONRESONANT TRANSMISSION LINES

All transmission lines are either resonant or nonresonant. A resonant line has characteristic standing waves, while a nonresonant does not.

Remember that a standing wave is the result of a certain amount of energy being reflected back along the transmission line. Imagine a transmission line so long that none of the energy sent out by the transmitter ever reaches the end of the line. Naturally, since none reaches the end, none can be reflected back. But of course no line is that long. So why not string up a line of convenient length and connect a device to the far end that will absorb all the energy traveling down the line? Since all the energy is absorbed, none will be left to be reflected back. This gives you a nonresonant line. To do this, the impedance of the absorber must match the impedance of the antenna. The absorber will collect all the energy fed into the line and feed that energy into the antenna to be radiated as a magnetic field.

A resonant line does not have its impedance matched to the impedance of the antenna. This type of line is actually an antenna whose length is some multiple—1, 2, 3, etc.—of a quarter-wave length. You fasten one end of the line to the antenna and the other end to the transmitter.

Resonant lines are usually open two-wire system, while the nonresonant line may be a two-wire, a concentric, a shielded, or a twisted-pair.

Figure 28 shows some examples of resonant transmission lines. To avoid confusion, only the current distribution lines are indicated in the illustration.

When building a resonant transmission line, find out whether the antenna is to be current-fed or voltage-fed. Also, remember that the length of the line must be some multiple of a quarter wave length; and that the input coupling device must fit the requirement of the line.

A transmission line for a voltage-fed antenna must have a length which is an odd multiple—1, 3, 5, etc.—of a quarter wave length, with a current input, as in figure 28a. A current-fed antenna used with a quarter wave length transmission line must have a voltage input, as in figure 28b.

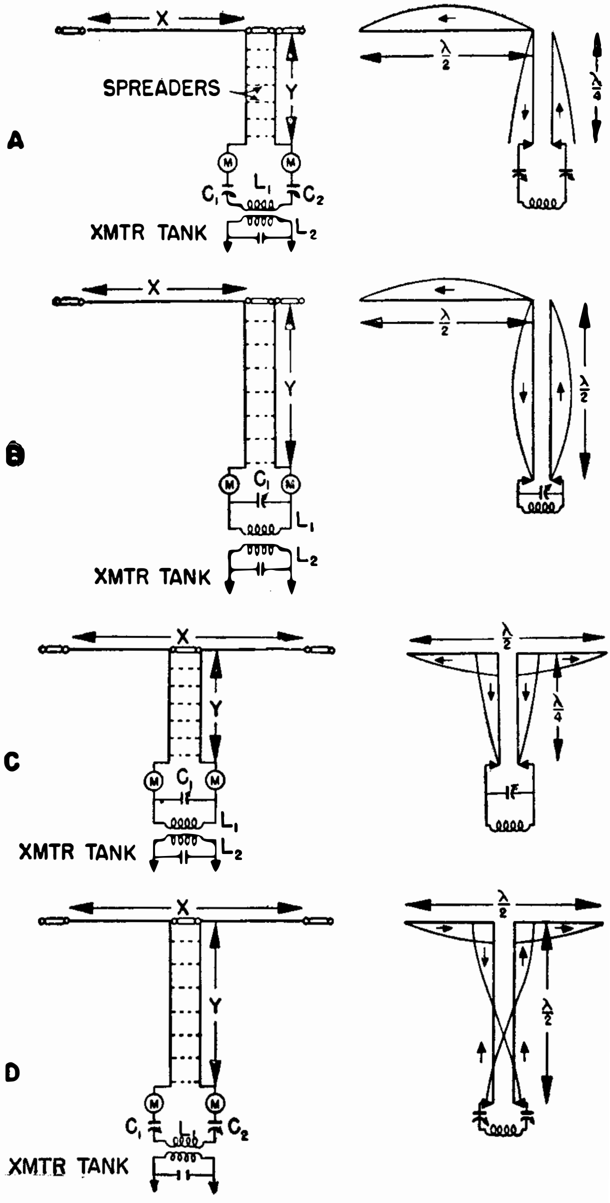


Figure 28.—Resonant transmission lines.

A transmission line whose length is an even multiple —2, 4, 6, etc.—of a quarter-wave length, must have a voltage input if the antenna is voltage-fed, as shown in figure 28c, and a current input if the antenna is current-fed, as in figure 28d.

The device used to produce a high current is shown in figure 29a. The condensers are adjusted so that the transmission line and the coil are resonant, and the current flow will be maximum.

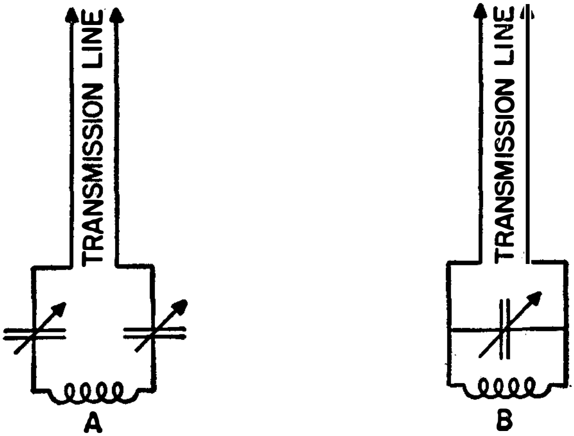


Figure 29.—Transmission line input devices.

The circuit in figure 29b is the coupling device used to produce a high-voltage input to a transmission line. The condenser is connected parallel with the inductance and the transmission line. At resonance, this combination offers high impedance, and the voltage is maximum.

ANTENNA COUPLING SYSTEMS

A number of methods are used to couple the power stage of the transmitter to the transmission line. Several of the more common systems are shown in figure 30.

Figure 30a is a simple system. It consists of a coil tightly coupled to the plate tank of the power amplifier

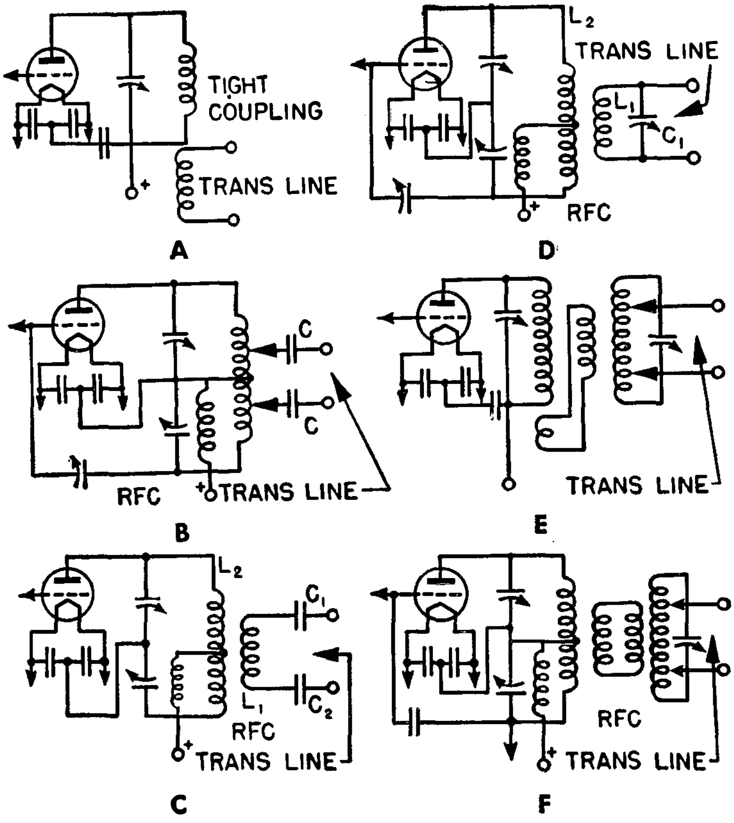


Figure 30.—Antenna coupling systems.

stage. If the current flowing in the power amplifier is less than normal, increase the coupling until current flow is correct.

The taps on the tank circuit in figure 30b are suitable for an open two-wire transmission line. The load on the power amplifier stage is increased by moving both taps outward the same distance from the center of the coil.

Figure 30c shows a series tuning circuit used to produce a high current, and 30d shows a parallel tuning system that provides a high voltage input to the transmission line.

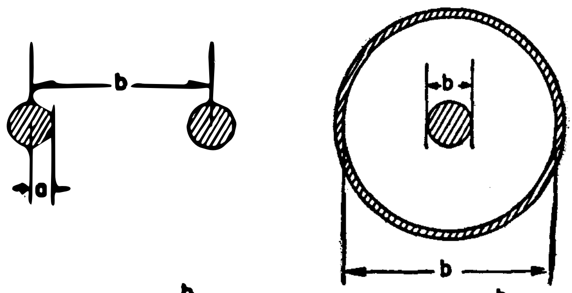
Figures 30e and 30f show link coupling systems. These two methods have the advantage of isolating the plate and antenna tanks. Figure 30f has the added advantage of tapping the bottom of the coil to reduce the effect of stray capacitance and inductance.

CHARACTERISTIC IMPEDANCE

The characteristic impedance of a transmission line is the impedance created by the distributed inductances and capacitance of the line itself. Characteristic impedance is indicated by the symbol Z_o.

Methods of determining the Z_o of either a two-wire or a concentric line are given in figure 31. The impedance of a two-wire line is determined by figuring the ratio of the wires.

The Z_o of a concentric line is determined by the ratio of the diameter of the inner wire to the inside diameter of the tube.



$Z_o = 276 \log_{10} \frac{b}{a}$ $\qquad$ $Z_o = 138 \log_{10} \frac{b}{a}$

Figure 31.—Methods of determining the characteristic impedance.

The following table shows a few representative values of practical two-wire transmission lines:

Wire gage	*Spacing (inches)*	*Z_o (ohms)*
# 6 B & S	14	600
# 8 B & S	11	600

Wire gage	*Spacing (inches)*	Z_o *(ohms)*
#10 B & S	8	600
#12 B & S	6	600
# 6 B & S	5½	500
# 8 B & S	4½	500
#10 B & S	3½	500
#12 B & S	2½	500

The graph in figure 32a can be used to find the characteristic impedance of a two-wire line. The impedance in ohms is found along the vertical line and the ratio of b/a is given along the base line. In the illustration given, b is 3 inches and a is ⅛ inch. The ratio of b/a is—

$$\frac{3}{1/8} = 24.$$

Locate ratio 24 on the base line and follow that line straight up to the curve. Read across to the left and find the impedance on the left-hand vertical scale. You will find it to be approximately 380 ohms.

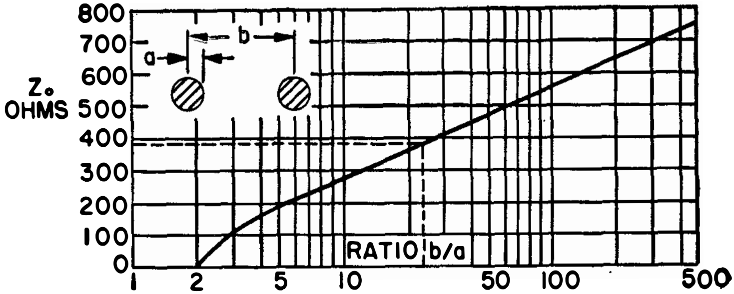
Figure 32b is a graph for determining the characteristic impedance of a concentric transmission line. The ratios of b/a are expressed across the base, the same as in figure 32a.

The characteristic impedance of a line is determined solely by the ratio b/a, and not by the length of the line. The characteristic impedance of a line 10 feet long is exactly the same as that of a smaller type line 100 feet in length.

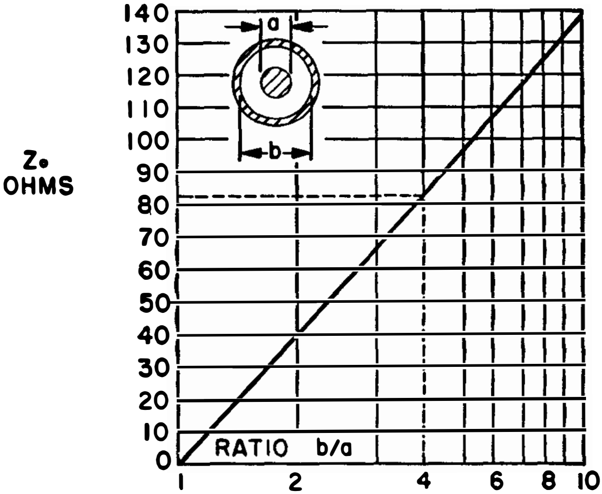
When you are using a nonresonant line, you can disregard its length. This advantage permits you to install a transmitter in any desirable location, since the length of the transmission line need not be held to a given number of quarter wave lengths.

IMPEDANCE-MATCHING DEVICES

The input, as well as the output, of a nonresonant transmission line must also match the Z_o of the line. Matching the input to the line can be done by either of the circuits shown in figures 30e and 30f. If you want



(A) TWO-WIRE LINE



(B) CONCENTRIC OR COAXIAL LINE

Figure 32.—Graphs for determining the characteristic impedance.

to increase impedance, move the variable taps on the antenna tank outward an equal distance from the center. To decrease the impedance, move the taps toward the center.

Several systems are used to match the Z_0 of the line to the antenna. The delta match is shown in figure 33.

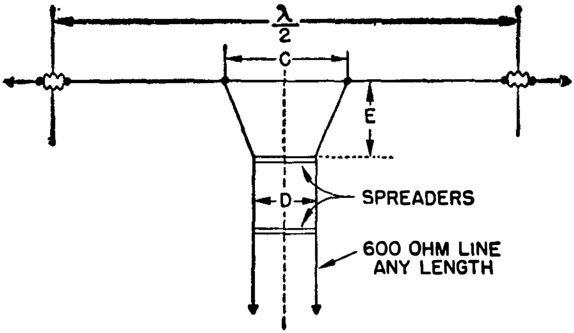


Figure 33.—The delta impedance match of a half-wave antenna.

Most two-wire transmission lines have a characteristic impedance of between 500 and 600 ohms. In figure 33, if you use 18-gauge wire, and D is 3 inches, the characteristic impedance will be approximately 600 ohms. To find the dimensions for C and E for a 600-ohm line, use the following equations—

$$C \text{ in feet} = \frac{148}{f\,(\text{megacycles})}$$

$$E \text{ in feet} = \frac{148}{f\,(\text{megacycles})}$$

Another common impedance-matching system uses two quarter-wave stubs. This method is shown in figure 34.

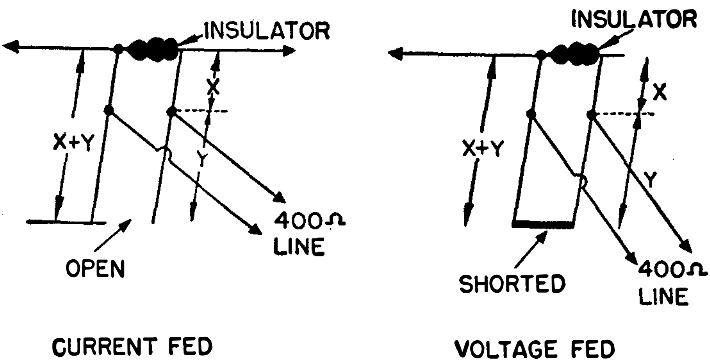


Figure 34.—Quarter-wave impedance-matching stubs.

The quarter-wave impedance-matching stub is used with either a current-fed or voltage-fed antenna. If the

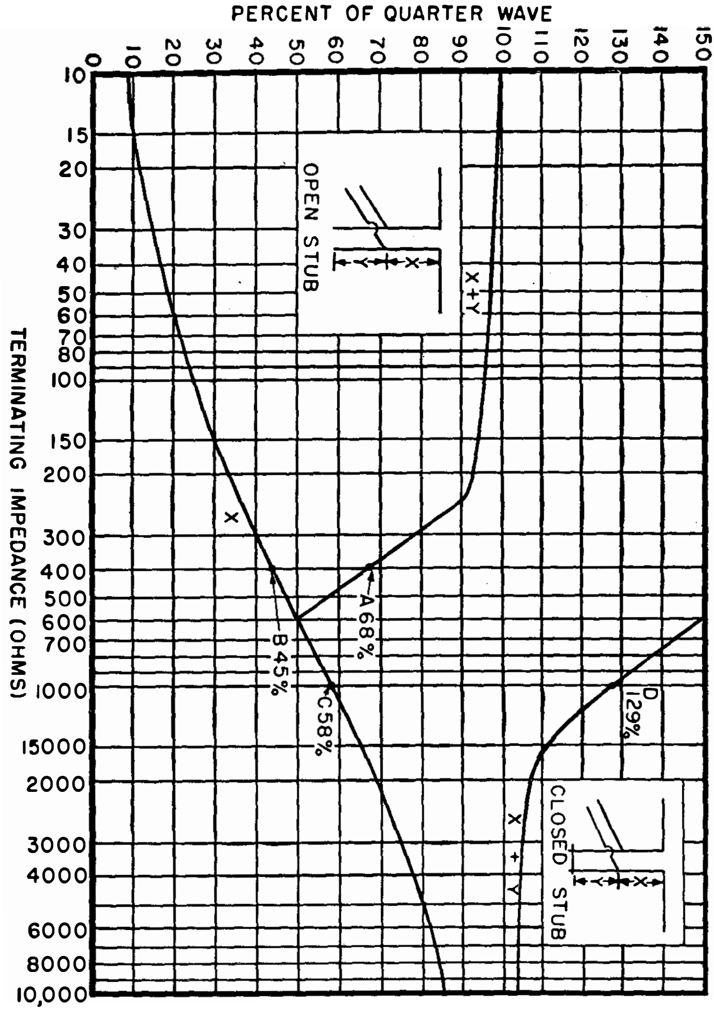


Figure 35.—Chart for computing the values of *X* and *Y* for the quarter-wave antenna-matching stubs.

antenna is current-fed, the ends of the stub are open, but if the antenna is voltage-fed, the matching stubs are shorted.

The values of X and Y can be computed from the table of figure 35. For example, you wish to match a 400-ohm line to a current-fed antenna. You'll have to use an open stub. If the wave length of the transmitter is 10 meters, the length of the whole stub—$Y + X$—is 68 percent of 10 meters, or 6.8 meters. The value of X will be about 45 percent of 10 meters, or 4.5 meters.

Notice that if the line has an impedance of 600 ohms, the value of (XY) and X are each equal to 50 percent of the wave length. In other words, the stub for a 10-meter length will be 5 meters, and the line will be attached to the end of the stub.

To match a 1,000-ohm line to a closed—shorted—stub, the length of $(X+Y)$ will have to be about 129 percent of the wave length, and X 58 percent. See point D on figure 35. For a 10-meter wave length, the entire stub $(X + Y)$ will be, $10 \times 1.29 = 12.9$ meters. And the length of X will be, $10 \times 0.58 = 5.8$ meters.

Matching a Concentric Line to Half-wave Center-fed Antenna

The task of matching a concentric line to a half-wave current-fed antenna is relatively simple. The impedance of most concentric lines is between 70 and 80 ohms, usually closer to 70 ohms. Since the radiation resistance of a half-wave antenna at its center is also about 70 ohms, a concentric line can be attached directly to the antenna without using any matching device.

Figure 36 shows the method of coupling a concentric line of approximately 70 ohms to a half-wave current-fed antenna. The degree of mismatching between the line and antenna is usually less with a concentric line than with a two-wire system using impedance-matching devices.

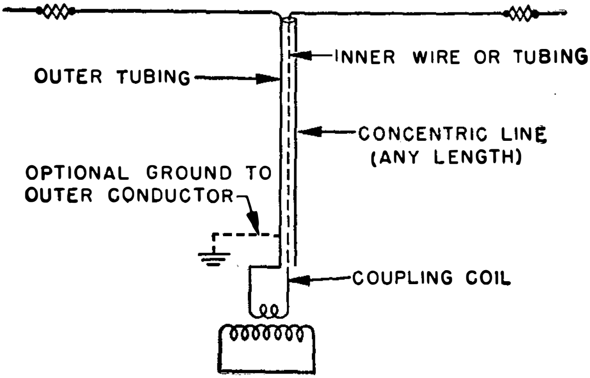


Figure 36.—Coupling a concentric line to a half-wave antenna.

Matching a Twisted-pair to Half-wave, Current-fed Antenna

The twisted-pair is the least efficient transmission line, but in emergencies you may have to use it to feed an antenna.

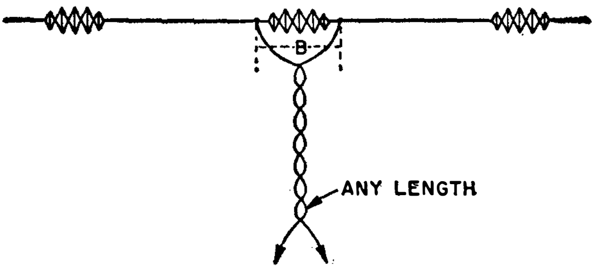


Figure 37.—Coupling a twisted-pair to a half-wave antenna.

The impedance match is achieved by making a *V* at the end of the twisted-pair. The length, *B*, of the opening of the *V* in figure 37 will depend upon the impedance of the line. To increase the impedance, you will increase the length of the opening. This length is between 15 and 18 inches for most lines. After the impedance match has been made, tape the bottom of the *V* securely to prevent further unwinding.

It is important that the twisted-pair be free from standing waves, or the line will become hot and burn the insulation at each spot where a current loop is present. When the line is first put into operation, check it for the presence of hot spots. If there are none, the degree of mismatch is not serious enough to materially affect the operation of the transmitter.

Check for Standing Waves

You will have to check a nonresonant transmission line for the presence of standing waves. If current or voltage

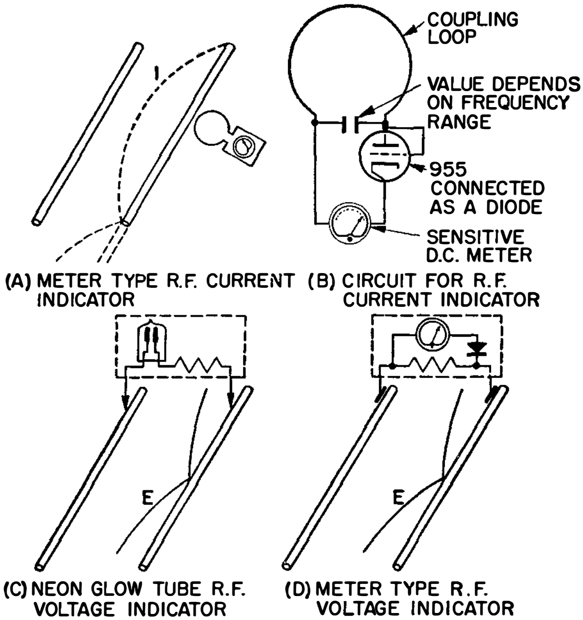


Figure 38.—Radio-frequency indicators used to check for standing waves.

nodes are present, the line must be adjusted to eliminate them.

You will use the equipment and circuits of figures 38a and 38b to show the presence of current loops. The circuits of figures 38c and 38d will show voltage loops. When your transmission line is adjusted so that no r. f. indication is given the line is nonresonant.

QUARTER-WAVE METALLIC INSULATORS

Use a piece of copper as an insulator? Ridiculous, you say? Well, usually; but under certain conditions with r. f., copper can be used as an insulator.

The supporting metal bars are a quarter wave length and are shorted at their base by another bar. Points *A* and *B* are points of high voltage and low current. By Ohm's Law

$$\frac{\text{high voltage}}{\text{low current}} = \text{high impedance.}$$

Thus a quarter-wave metal bar can serve as an excellent insulator between the transmission line and ground.

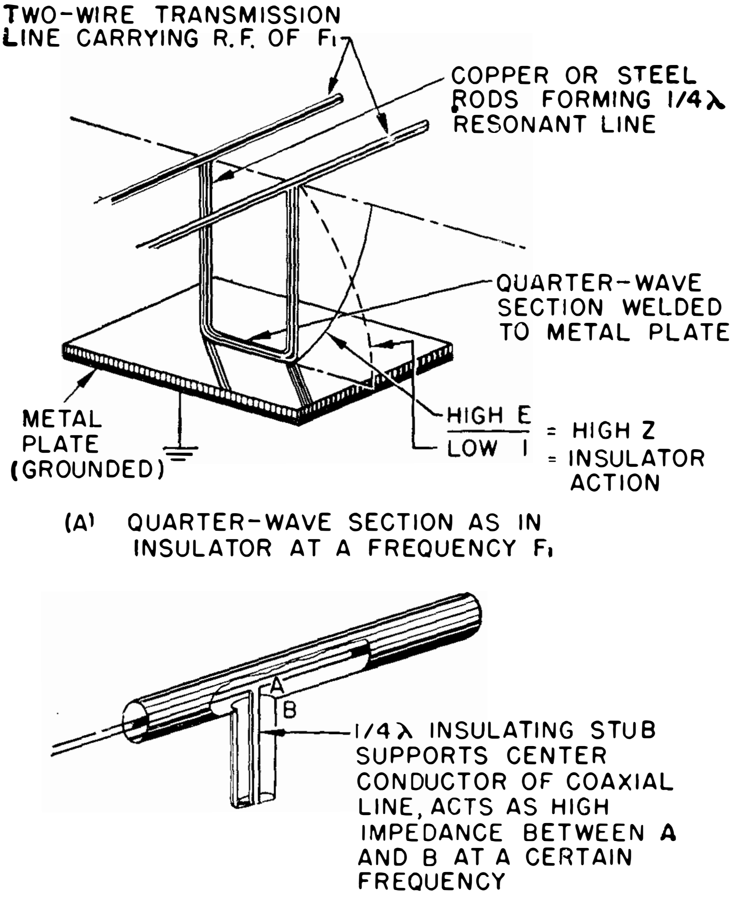
But here is the disadvantage to this system—a transmission line using metallic insulators can be used with only one frequency. For any other frequency the insulators will not have the correct length.

The quarter-wave metallic insulators may also be used as filters. Any frequencies other than those for which the line is constructed will be shorted out.

DIRECTIONAL ANTENNAS

Certain types of Navy tactical equipment require the use of antennas that will project their fields in only one direction. Although all antennas direct their energies best in one direction, the term directional antennas refers specifically to systems which are designed to concentrate all their radiations into a single narrow beam or lobe.

Directional antenna systems have two parts, the radiator and the reflector. The radiator may be a combination or array of dipoles or may be the open end of a tube or wave guide. The reflector may be other dipoles, a solid piece of sheet metal screen or bedspring.



(A) QUARTER-WAVE SECTION AS IN INSULATOR AT A FREQUENCY F1

(B) QUARTER-WAVE COAXIAL STUB AS AN INSULATING SUPPORT ON A COAXIAL TRANSMISSION LINE

Figure 39.—Quarter-wave metallic insulators.

PRODUCING LOBES WITH PHASED ARRAYS

One way to produce lobes is to place several dipoles end to end as in figure 40, and connect them so they all are fed in phase. Two dipoles will produce the pattern of figure 40a. The addition of the third and fourth dipoles will cause the lobe to become narrower, as in figures 40b and c. Add more dipoles and several minor lobes will appear in addition to the two major lobes.

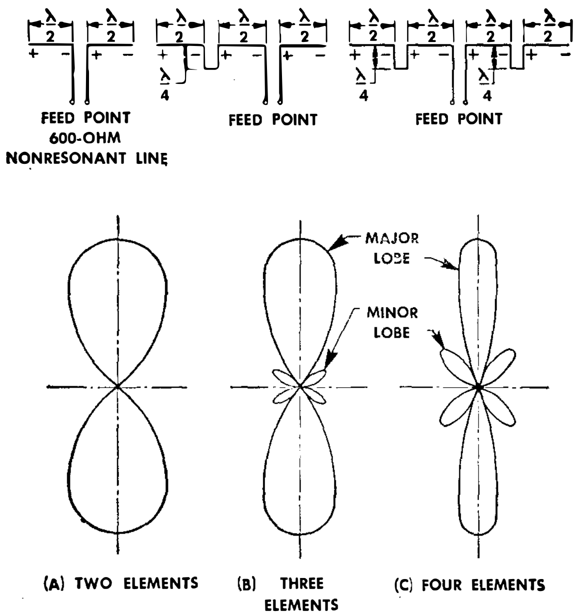


Figure 40.—Lobes produced by colinear arrays.

The arrangement of dipoles shown in figure 40 is a colinear array. There are many modifications of this array, but the basic principle of producing a sharper lobe by adding more elements remains the same.

The broadside array shown in figure 41 is composed of four colinear arrays stacked on top of each other. The

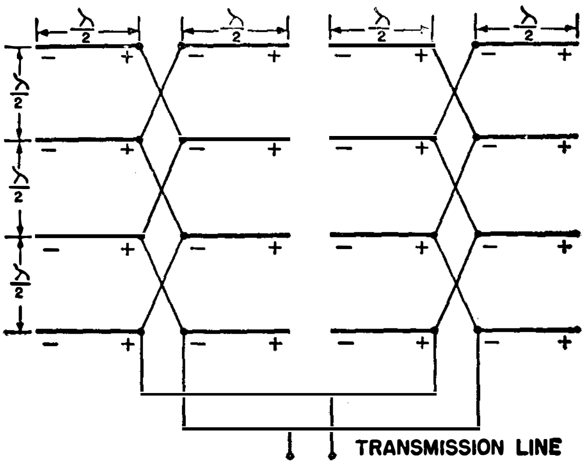


Figure 41.—Broadside or bedspring array.

connections and relative polarities are indicated. The spacing between each row is one-half wave length.

Without a reflector, the broadside array will produce a narrow beam in two directions at right angles to the array. A one-direction lobe is produced by placing a similar broadside array or a metal screen at a distance of one-tenth to one-quarter wave length behind the first array of dipoles. Since the broadside array of figure 41 is four half-waves wide by four half-waves high, it is called a "4 x 4" array.

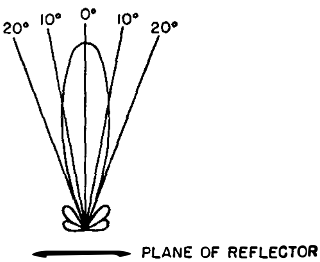


Figure 42.—Vertical width of the lobe formed by a "4 x 4" broadside array.

A 4 x 4 array with a suitable reflector produces a lobe that is approximately 20° wide and 7° high. A horizontal beam narrower than 20° can be obtained by adding more elements to increase the length of the array. A narrower vertical beam can be obtained by increasing the number of stacked elements.

Since each dipole in a broadside array must be one-half wave length long, you can see that a directional antenna can be practical only at relatively high frequencies—200 to 300 mc. Each element for a 200-mc. frequency will be about 30 inches long.

Parasite Arrays

Lobes may also be produced by placing parasite elements near the driven dipole antenna, as in figure 43. If the parasite element is slightly longer than a half wave length, it will act as a reflector by absorbing the energy of the back lobe, and will reradiate this energy in proper phase to increase radiation in the direction past the driven dipole.

When the parasite unit is shorter than one-half wave length, it is called a director, and will absorb and reradiate the energy away from the driven element, as in figure 43b.

The reflector and director can be compared to the reflector and lens of a searchlight. The mirror behind the source of light reflects, while a lens in front concentrates or directs the light into a narrow beam.

The reflector and director in an array are housed in a single unit. It is common practice to use one reflector and two directors with one driven element. This arrangement appears in figure 43.

The reflector is usually placed about 0.15 of a wave length behind the driven element, and the directors are spaced about 0.1 to 0.2 of a wave length in front of this element.

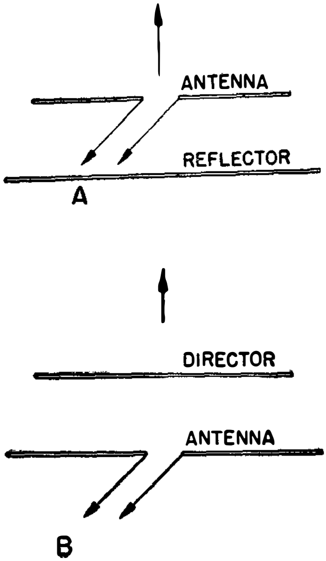


Figure 43.—Antennas with parasitic elements.

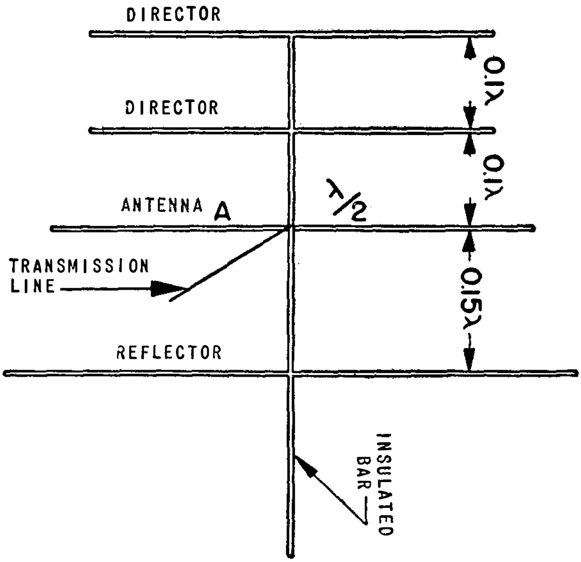


Figure 44.—Four element parasitic antenna.

Quasi-light Theory or Microwave R-F

Microwave r. f. is said to be quasi in character—quasi being a Latin word meaning "resembling" or "similar to"—because the behavior of microwave r. f. resembles that of light. In other words, microwave r. f. and light waves obey the same laws of reflection and refraction.

You have seen how a beam of light strikes a wall or mirror and is reflected back into space. Microwave r. f. is reflected in the same way if it is aimed at a piece of metal or some other reflecting surface. You can understand the action of microwave r. f. reflector if you remember what you have seen happen to reflected beams of light.

Safety Precautions

The first thing to do when working on antennas is to get permission from the CWO and the OOD. When you have completed work on the antennas inform the OOD and the CWO that you are through working aloft.

While antennas are energized by radio transmitters men are not permitted to go aloft except by means of ladders and landings rendered safe by grounded hand rails or similar structures, unless it is definitely determined in advance by suitable tests that no danger exists. This will prevent casualty due to involuntary relaxation of the hand which might occur if a small spark is drawn from a charged piece of metal or section of rigging. The spark itself may be quite harmless. Safety belts are always worn by men working aloft.

Men are not permitted to work on any antenna when that antenna or other antennas in the immediate vicinity are energized by radio or radar transmitters unless it is definitely determined in advance that no danger exists. On board ship "other antennas" means any antenna on board a ship moored alongside, across a pier, or at nearby shore radio stations. Circuits opened to deenergize equipment must be tagged to prevent their being closed while men are working on the gear.

Warning signs and suitable guards must be provided to prevent personnel from coming into accidental contact with high voltages. Figure 45 shows a typical danger or warning sign.

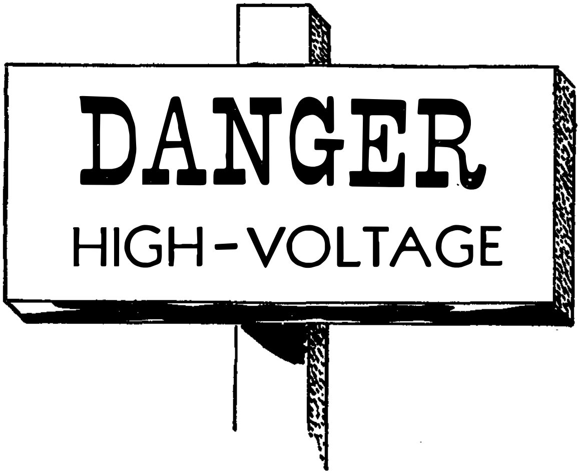


Figure 45.—Warning sign.

HF Operating Hazards

High-frequency transmitters must not be operated on frequencies in excess of 10 mc. when the radiating portions of antennas connected to such transmitters are less than the following distances from the hazard centers defined below.

Rated power of transmitters:	*Distance (feet)*
50 watts or less	15
51 to 200 watts	25
201 to 1,000 watts	50
Over 1,000 watts	75

The radiating portion of an antenna includes the entire exposed portion not enclosed in a trunk or tube such as employed in a concentric transmission line. This does not apply to shielded and grounded shipboard installations.

The following are considered hazard centers:

1. All guns fitted with electric-firing circuits, either during the process of loading or in the loaded condition.

2. All guns using separate ammunition, percussion or electric firing, during the process of loading.

3. Gasoline fueling operations involving the delivery of gasoline from hoses, spouts, cans, etc., or any place where gasoline vapors are present.

4. Aircraft employing unshielded flare circuits whenever flares are installed.

5. Powder-handling operations involving open tanks or exposed powder.

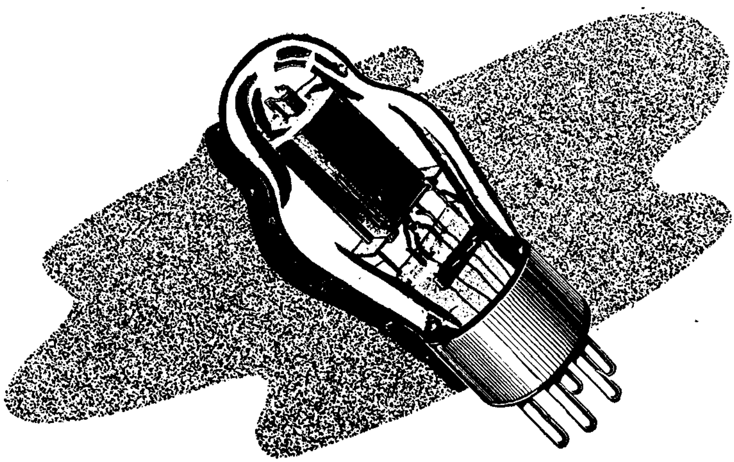
6. Oil-fueling operations during the interval of time required to make or break metallic-hose connections.

7. Electrically fired detonators shall not be exposed within 10 feet of any exposed transmitting apparatus or exposed transmitting antenna leads. No danger exists with percussion detonators, or detonators of any type while in covered metal containers.

QUIZ

1. What is the purpose of checking nonresonant transmission lines?
2. What are the two parts of directional antenna systems?
3. What is a standing wave?
4. What must be done to the antenna each time the frequency of the transmitter is changed?
5. What are the four general types of transmission lines used with frequencies below 300 mc.?
6. What type of antennas are used extensively with portable equipment?
7. On board ship what is meant by "other antennas"?

8. What is the upper frequency limit that the pressurized concentric line will work?
9. Which type of transmission line is least efficient?
10. What determines the gain in an rhombic antenna?



CHAPTER 4

VACUUM TUBES

THE START

In the year 1883, Thomas A. Edison almost discovered how the vacuum tube worked. In his experiments with the incandescent light bulb, he was troubled by the repeated breaking of the fragile carbon filament. To give the filament more strength, he placed supporting wires alongside, but not touching the filament. A small piece of insulation provided the bracing link.

One day, Edison attached the positive terminal of a battery to the supporting wire and the negative terminal to the filament circuit. To his surprise, he saw that a current was flowing out of the bulb through the supporting wire. This was not according to the rules, since there was no conductor connecting the filament and the wire. Because he did not understand that current represents the flow of electrons, he wrote in his notebook—"When the positive terminal of a battery is connected to the supporting wire, a current seems to flow. This is an INTERESTING but WORTHLESS observation."

Interesting but worthless? In this case the observation paid dividends, but years later. In 1904, J. Ambrose Fleming, an English scientist who understood the flow of electrons, started to experiment with Edison's WORTHLESS observation.

He replaced the supporting wires with a large metal plate. With this new tube he conducted many experiments, the results of which are summed up in the following statements:

1. When a filament is heated until it is red hot, electrons will be given out by the metal and will form a cloud about the filament.
2. When a positive potential is placed upon the plate, these electrons will flow from the filament to the plate. By placing larger voltages on the plate, the rate of flow can be increased up to a certain point, beyond which no additional current can be made to flow.
3. If a negative potential is placed upon the plate, no current will flow in either direction.

Because Fleming discovered that current could flow in only one direction, the tube was know as "Fleming's Valve." The English vacuum tube is still called a valve.

Back in the United States, Lee DeForest conducted an experiment in 1907 that had been suggested by Fleming. DeForest placed a screen of fine wire between the filament and the plate. He found that when these wires were made more negative than the filament, the flow of electrons to the plate was reduced. If the screen was made more and more negative, the flow was reduced still further. If the screen was made negative enough, the flow was stopped completely. The wires of this screen were wound on a frame so that they resembled the yard markers on a football field or gridiron. For that reason the screen is called a GRID.

The use of the grid in a vacuum tube to control the flow of current from the filament to the plate is one of the most important discoveries in electricity. The grid allowed the vacuum tube to grow up.

First you will study the simple vacuum tubes and take up the more complex types later. Regardless of the number of elements that are included within a single glass envelope, every vacuum tube goes back to the principle discovered in Edison's "worthless" observations—electrons are given off by a hot metal filament.

In order to understand vacuum tubes, a knowledge of electrons is essential. The properties of electrons are reviewed in the following information.

All matter or substances consist of various combinations of atoms. Atoms consist of positive nuclei with various numbers of electrons revolving and vibrating around these positive nuclei. The solar system with the planets revolving around the sun is similar in arrangement to that of some atoms. The farther away an electron in its vibrations gets from its positive nucleus the less the attraction and the easier the electron can be pulled away to an adjacent atom. All electrons are alike. They are always negative charges of electricity, whether in an atom of gold, copper, hydrogen, oxygen, or any other substance.

Electric potential (voltage) causes the electrons to be pulled along the conductor from one atom to another, from negative to positive. This movement of electrons causes the conductor to heat. The greater the potential the greater the current and the greater the heat. The higher the temperature the greater the speed with which the electrons revolve and vibrate.

As the current (heat) in a conductor is increased the speed of the electrons reaches the point where they will leave the surface of the conductor. This is similar to heating water until it boils, causing steam to rise. The conductor must be heated until the electrons have a vibrating speed of around 620 miles per second before they will leave the filament.

THE ELECTRON

The whole foundation of electricity is based upon the electron, a minute negatively charged particle. Atoms, of which all matter is composed, consist of a positively charged nucleus around which are grouped a number of electrons. The physical properties of any material depend upon the number of electrons and the size of the nucleus. In all matter there are a certain number of free electrons. The movement of these free electrons is known as a current of electricity. If the movement of electrons is in one direction only, the current as you know is direct. If, however, the source of voltage is alternated between positive and negative, the flow of electrons will likewise alternate. This of course is known as alternating current.

If certain metals, or metallic substances such as metallic oxides, are heated to a high temperature either by means of a flame or by passing current through them, they have the property of throwing off, or emitting, electrons. The element of a vacuum tube which is heated to emit electrons is called the cathode.

If the cathode is heated to a high temperature in the open air, it will burn up because of the presence of oxygen in the air. For this reason the cathode is placed in a glass or metal bulb from which all air has been removed. Such a space is known as a vacuum. Since it is difficult to heat an element in a vacuum tube by means of fire or flame, the cathode, which is in the form of a filament, is directly heated by passing a current through it.

Any isolated positively charged body in the vicinity of the electron emitter will attract the negatively charged electrons. The positive charge on the body will soon be canceled by the electrons attracted to it unless some means is employed to remove the electrons as fast as they arrive. This can be done by connecting a source of constant voltage between the positively charged body and the electron emitter (fig. 46). This is the general arrangement in a two-element tube, or diode. It is also the basis of operation of all types of vacuum tubes.

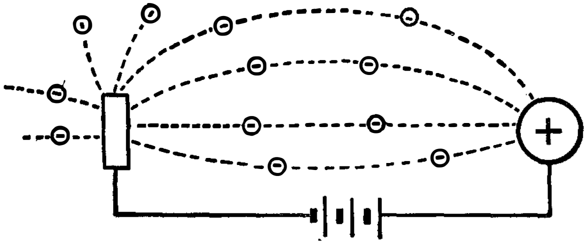


Figure 46.—Emitted electrons attracted by a positively charged body.

The emitter, or cathode, of a vacuum tube may resemble the familiar incandescent lamp filament which is heated by passing a current through it. The positively charged body usually surrounds the emitter and is called the plate, or anode. It should be noted that electrons travel from negative to positive.

Two types of cathodes, or emitters, are used in radio tubes. In one, known as the filament or directly heated type, the heating current is passed through the cathode itself. In the other, known as the indirectly heated type, the current is passed through a heating element, which in turn heats the cathode to a temperature sufficiently high for electron emission. In the indirectly heated type, the cathode is an oxide-coated metal sleeve which is placed over the heater element.

The higher the temperature of the cathode, the more electrons it will emit. However, if too much voltage is applied to a cathode, the heavy current flow will cause the filament or heater to burn out. The safe filament or heater voltage is determined by the manufacturer, and this voltage rating must be observed for satisfactory operation. The cathode of a tube will not continue to emit electrons indefinitely. After several thousand hours of operation, the number of electrons emitted will gradually decrease, until finally an insufficient number is emitted for proper operation. The decrease in emission capacity is due to the chemical change which takes place in the cathode. This is one of the reasons why tubes wear out.

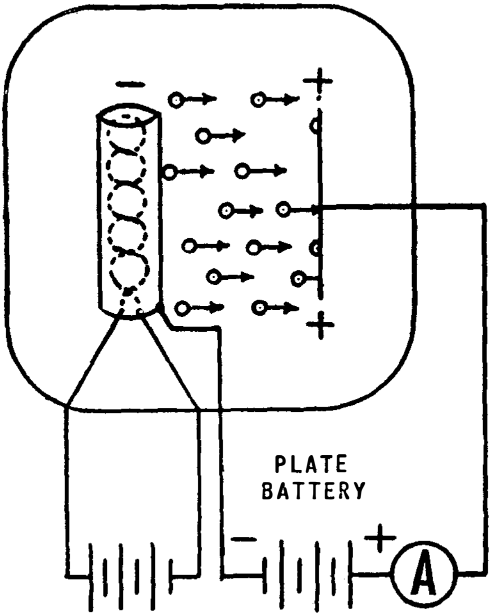


Figure 47.—Electron flow in a diode when plate is positive.

OPERATION OF DIODE

The diode is the simplest type of vacuum tube, and consists of only two elements: a cathode and a plate. The operation of the diode depends on the fact that if a positive voltage is applied to the plate with respect to the heated cathode, current will flow through the tube; if a negative voltage is applied to the plate with respect to the cathode, current will not flow through the tube.

When the positive terminal of a battery is connected to the plate of a diode and the negative terminal is connected to the cathode, the plate will be positive with respect to the cathode. Since the electrons emitted by the cathode are negative particles of electricity, and there is a positive charge on the plate, the electrons emitted by the cathode will be drawn to the plate (fig. 47). In other words, there is an electron flow through the tube, which results in a current flow in the circuit. If the flow of current in the circuit is measured by meter *A* (fig. 47), while the voltage applied to the plate (known as battery voltage or plate voltage) is increased, it will be seen that the

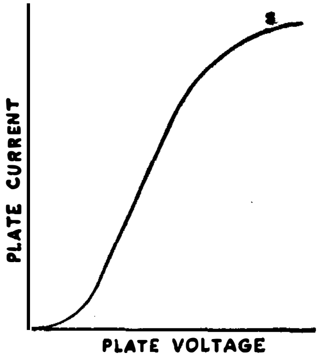


Figure 48.—Plate current flow in a diode.

current flow through the tube, known as the plate current, increases. This is illustrated by the plate-voltage, plate-current curve of figure 48.

When the negative terminal of a battery is connected to the plate of the diode and the positive terminal is connected to the cathode (fig. 49), the plate will be negative with respect to the cathode, and therefore no electrons will be attracted to the plate. Since no electrons are traveling across to the plate, no current will flow through the tube.

The diode is a conductor when the plate voltage is positive, and is a nonconductor when the plate voltage is negative. This property of the diode permits the use of this tube for two very useful functions: rectification and detection.

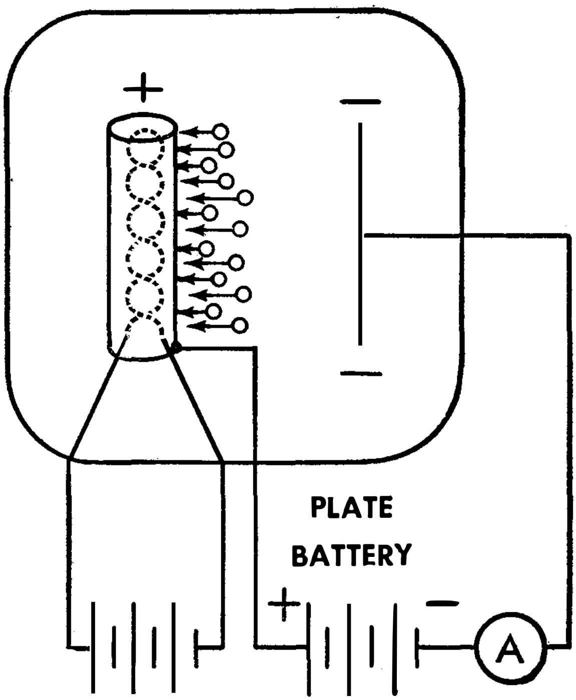


Figure 49.—Diode action when plate is negative.

DIODE AS A RECTIFIER

The ability of a diode to conduct, or pass, current in only one direction makes possible its use as a rectifier to convert alternating current into direct current. A diagram of a simple diode rectifier circuit is shown in figure 50. If an a. c. source is connected between the plate and the cathode of such a circuit, one half of each a. c. cycle will be positive and the other half will be negative. Therefore, the plate of the diode will be made alternately positive and negative with respect to the cathode. Since the diode conducts only when the plate is positive, current

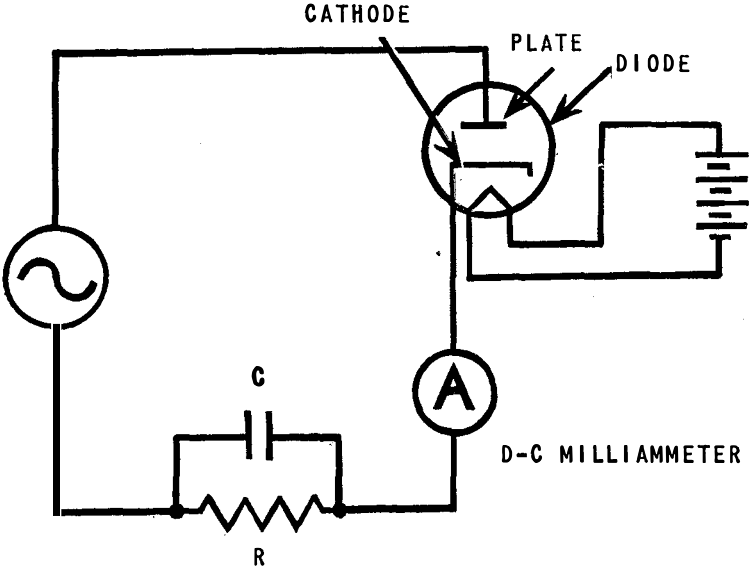


Figure 50.—Diode used as a half-wave rectifier.

flows through the tube only on the positive half-cycles of the a. c. voltage, as shown in figure 51. Since the current through the diode flows in one direction only, it is direct current. This type of diode rectifier circuit is called a half-wave rectifier, since it rectifies only during one-half of the a. c. cycle.

It can be seen from figure 51 that this direct current is quite different from pure direct current, since it rises from zero to a maximum and returns to zero during the positive half-cycle of the alternating current, and does not flow at all during the negative half-cycle. To distinguish this type of current from pure direct current, it is referred to as pulsating direct current, or rectified alternating current.

To convert this rectified alternating current into pure direct current, the fluctuations must be removed. In other words, it is necessary to cut off the humps at the tops of the half-cycles of current flow, and to fill in the gaps due to the half-cycles of no current flow. This process is called filtering.

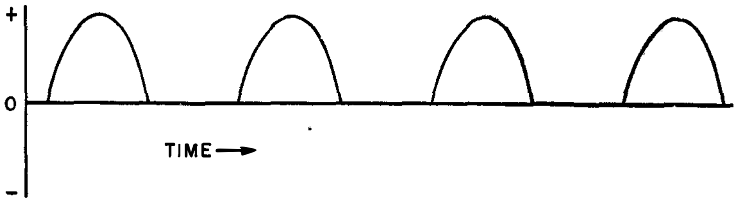


Figure 51.—Output of a half-wave rectifier.

In the circuit of figure 50, the d. c. voltage output will appear across the load resistor *R*, because of the current flowing through it during the positive half-cycles. The capacitor *C*, having a small reactance at the a. c. frequency, is connected across this resistor. This capacitor will become charged during the positive half-cycles, when voltage appears across resistor *R*, and will discharge into resistor *R* during the negative half-cycles, when no voltage appears across the resistor, thus tending to smooth out, or filter, the fluctuating direct current. Such a capacitor is known as a filter capacitor. It stores up voltage when it is present, and releases the voltage into the circuit when it is needed.

Figure 52 shows the voltage appearing across resistor *R*, both with and without a filter capacitor in the circuit. It will be seen that the addition of a filter capacitor alone is not enough to remove completely the fluctuations or ripple. In fact, no amount of capacitance, however large, would completely eliminate this ripple. However, if a filter circuit is added to the half-wave rectifier, as shown by the complete circuit (fig. 53), a satisfactory degree of filtering can be obtained. In this circuit, capacitors C_1 and C_2 are both filter capacitors, and fulfill the function described above. Inductor L is a filter choke having high reactance at the a. c. frequency and a low value of d. c. resistance. It will oppose any current fluctuations, but will allow direct current to flow unhindered through the

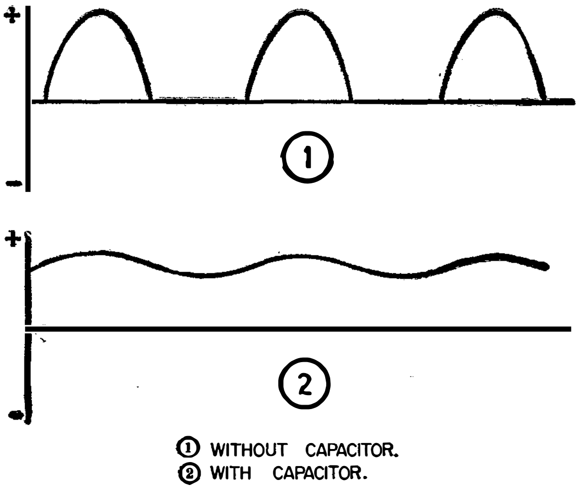


Figure 52.—Effect of filter capacitor.

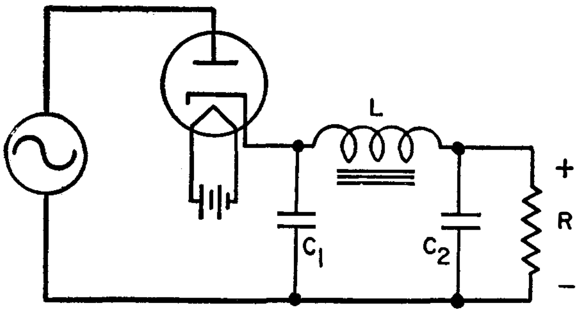


Figure 53.—Filter circuit added to half-wave rectifier.

circuit. The two filter capacitors C_1 and C_2 bypass the ripple voltage around the load resistor R, while choke coil L tends to oppose the flow of any ripple current through the resistor.

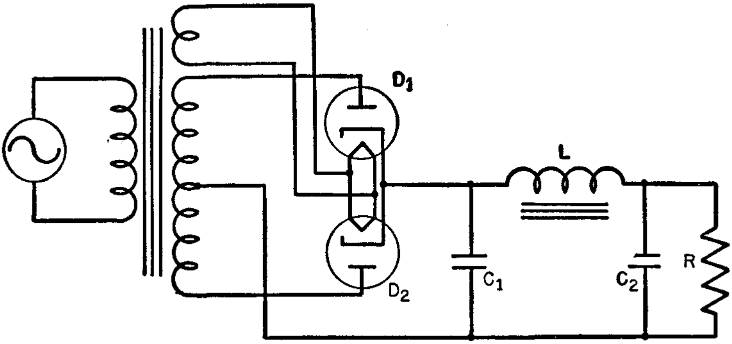


Figure 54.—Full-wave rectifier circuit.

The disadvantage of the half-wave rectifier is that no current flows during the negative half-cycle. Therefore, some of the voltage produced during the positive half-cycle must be used to filter out the ripple. This reduces the average voltage output of the circuit. Since the circuit is conducting only half the time, it is not very efficient. Consequently, the full-wave rectifier, so called because it rectifies on both half-cycles, has been developed for use in the power supply circuits of modern receivers and transmitters. In the full-wave rectifier circuit shown in figure 54, two diodes are used, one conducting during the first half-cycle and the other during the second half-cycle.

In the circuit of figure 54, the transformer has a center-tapped secondary winding, so that diode D_1 is connected to one half of this winding, while diode D_2 is connected to the other half. Resistor R is the load resistor common to both diodes. Capacitors C_1 and C_2 and inductor L form the filter circuit. During one half-cycle the plate of diode

D_1 will be positive with respect to the center tap of the transformer secondary winding, while the plate of diode D_2 will be negative. Consequently, diode D_1 will conduct while diode D_2 will be nonconducting. During the other half-cycle, D_1 will be negative and nonconducting while D_2 will be positive and conducting. Therefore, since the two diodes take turns in their operation, and one of them is always conducting, current flows through the load resistor during both halves of the cycle. This is full-wave rectification.

If no filter circuit were used in the full-wave rectifier circuit of figure 54, the d. c. output voltage across the load resistor R would appear as in figure 55. Obviously, this voltage wave form is much easier to filter than the

Figure 55.—Output of a full-wave rectifier.

half-wave rectifier output, and the action of the capacitors and inductors in smoothing out this wave form is the same as for the half-wave rectifier voltage.

The circuit shown in figure 54 is the basis for all a. c. operated power supplies used to furnish the d. c. voltages required by transmitters and receivers. Note that the heater voltage for each of the two diodes is taken from a special secondary winding on the transformer.

MERCURY VAPOR RECTIFIERS

The hot cathode mercury-vapor rectifier tube is similar to the high vacuum, except that a certain amount of mercury vapor is injected into the tube under a very low pressure. This type of tube is a more efficient rectifier than the high-vacuum tube, because of the constant low voltage drop in the tube during normal operating conditions. This voltage drop is generally around 15 to 20 volts and remains practically constant under normal changes in load, in comparison to the high-vacuum rectifier, which has a varying drop, the amount depending upon the type of tube.

The voltage drop in a rectifier tube is due to the effect of the space charge having to be overcome by the plate potential in order to have current flow. In order to explain the operation of the mercury-vapor tube it is first necessary to repeat the operation of the high vacuum tube and then conditions already existing, lead to ionization and changes in current when they are not wanted. Likewise keep the tube out of magnetic fields because such fields have the effect of changing the energies of the electrons in the atoms of mercury vapor, by distorting their hypothetical orbits and making certain directions of motion easier than others. Much difficulty in filtering in the output of the rectifier can be eliminated by isolating the power supply from the other circuits.

DIODE CHARACTERISTIC CURVES

The plate-current, plate-voltage curve shown in figure 48 is an important characteristic of the diode vacuum tube, because it shows the amount of current that a diode will pass for any given plate voltage. Different types of diodes may have slightly different characteristic curves. All of these curves, however, indicate one important fact: the load, or plate, current is not proportional to the applied, or plate, voltage. For this reason Ohm's law is strictly applicable only to small increments, or changes, of currents and voltages. In general, current-voltage relations in vacuum-tube circuits are studied by means of experimentally obtained characteristic curves.

The curved portions, or bends, in the graph of figure 48 are the result of certain variations in the action of the diode. When the plate voltage is low, the electrons nearest the cathode are repelled back to the cathode by the accumulated emitted electrons which are a little farther from the cathode, and only those electrons which are nearest the plate are attracted to the plate. This repelling effect around the cathode is known as the space charge. For intermediate values of the plate potential, the space charge in the vicinity of the cathode is reduced by the attraction of more electrons to the positively charged plate, and any increase in plate potential produces an appreciable increase in current, as shown by the curve of figure 48. For large values of plate potential, when the space charge is completely removed, the number of electrons reaching the plate per second is limited by the number emitted per second by the cathode, and is independent of plate potential. This latter condition is referred to as saturation, and a place along the curve (point *S* in fig. 48) is called the saturation point.

OPERATION OF TRIODE

The triode differs in construction from the diode only in the addition of another element, called the grid. The grid is a cylindrical structure made of fine wire mesh, which is placed between the cathode and the plate of the tube so that all the electrons leaving the cathode must pass through it in order to reach the plate. Figure 56 is a drawing which shows the arrangement of the grid, cathode, and plate in a typical triode. The grid is placed considerably closer to the cathode than is the plate, and consequently will have very great effect on the electrons which pass through it.

If a triode is connected in a simple circuit, as shown in figure 57, the action of the grid can be studied. When a small negative voltage (with respect to the cathode) is put on the grid, there is a resultant change in the flow of electrons within the vacuum tube. Since the electrons are negative particles of electricity, and like charges repel one another, the negative voltage on the grid will tend to repel the electrons emitted by the cathode, and thus tend to prevent them from passing through the grid on their way to the plate. However, since the plate is con-

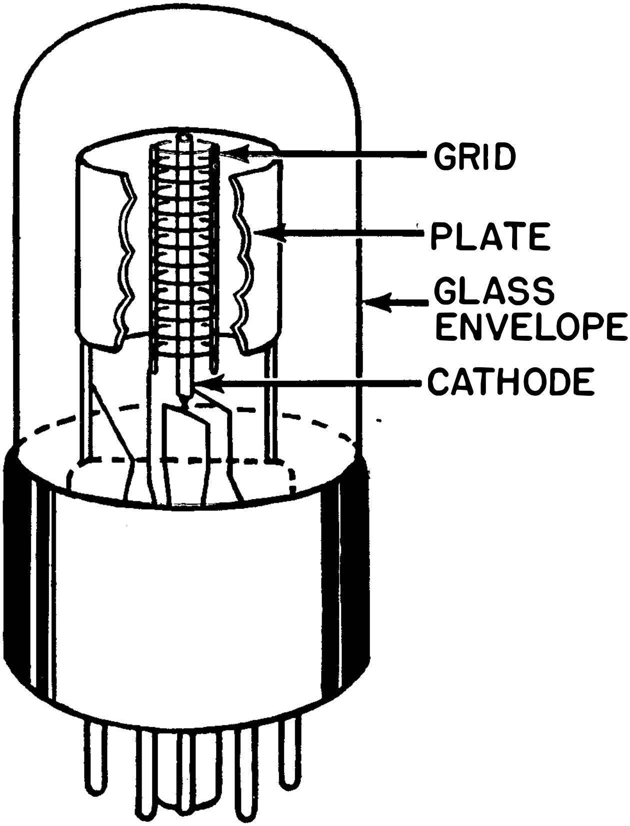


Figure 56.—Typical triode.

siderably positive with respect to the cathode, its attraction for the electrons is sufficiently strong to enable some of them to pass through the grid and reach the plate in spite of the opposition offered them by the negative voltage on the grid. Thus, a small negative voltage on the grid of the tube will reduce the electron flow from the cathode to the plate (fig. 58), and consequently will reduce the value of plate-current flow between the cathode and the plate of the tube.

If the plate current in the circuit of figure 57 is measured by means of meter *A*, while holding the plate

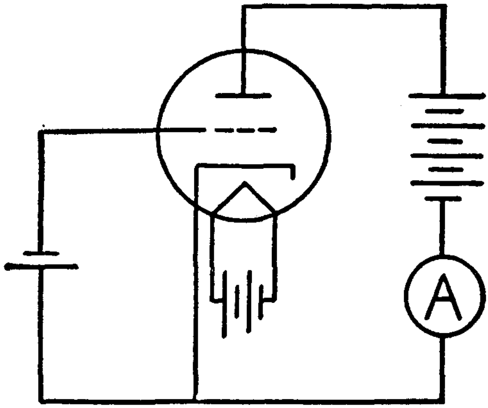


Figure 57.—Triode with a small negative voltage on the grid.

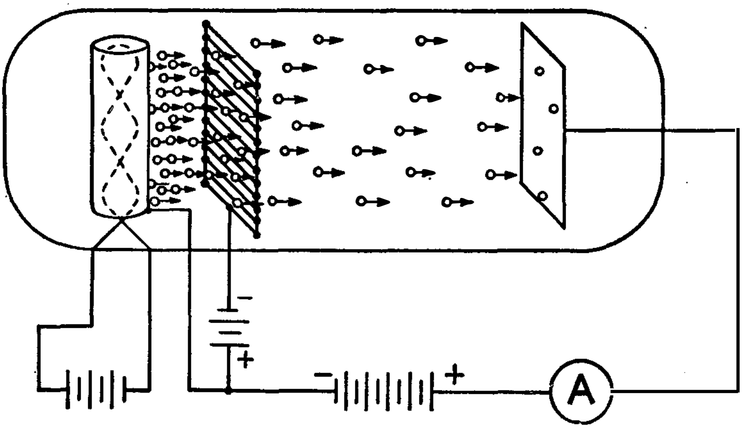


Figure 58.—Effect of negative grid on plate-current flow.

voltage constant and making the grid of the tube gradually more negative with respect to the cathode, the plate current will vary as shown in the grid-voltage, plate-current curve of figure 59. Such a curve is also known as an E_g—I_p characteristic curve. From this curve, it can be seen that as the grid of the tube is made more negative, less plate current will flow, since the more negative the grid the fewer electrons it permits to pass on to the plate. In the case of this particular tube (type 6C5), it will be noted from the characteristic curve that if the grid is made sufficiently negative (— 10 volts), the plate current drops to zero. Thus, this value of negative grid voltage has cut off the flow of electrons within the tube. A negative voltage which is applied to the grid of a tube to hold its plate-current flow at a given value is known as the grid-bias voltage, or more simply, the bias; that value of grid bias which will cut off the flow of plate current is called the cut-off bias for that tube. Since the plate current in a tube increases as the plate voltage is increased, the bias required to cut off plate-current flow will increase as the plate voltage applied to the tube is increased.

The triode is now connected in a circuit (fig. 60) where an a. c. (signal) voltage is applied to the triode, in addition to the grid-bias voltage. The a. c. signal source is adjusted so that it applies 1 volt of a. c. voltage to the circuit. Since the signal source and the 3 volts of negative bias are in series, on the positive half-cycle of the a. c. signal there will be — 2 volts applied to the grid with respect to the cathode ($+1-3=-2$) ; on the negative half-cycle there will be —4 volts on the grid on the tube ($-1-3=-4$). From the grid-voltage plate-current curve shown in figure 59, it can be seen that when there is no a. c. signal applied to the tube, the plate current will be fixed at 8 milliamperes by the 3 volts of bias supplied by the bias battery. When the a. c. signal is applied to the tube, on the positive half-cycles there will be — 2 volts on the grid of the tube and the plate

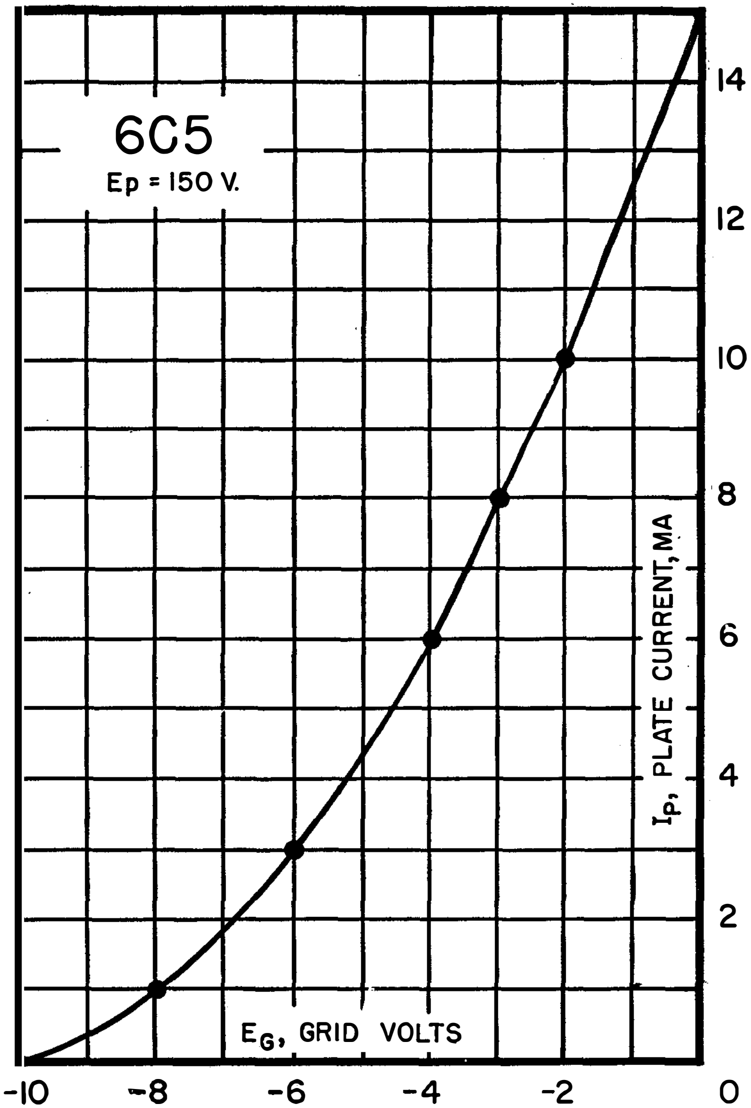


Figure 59.—Grid-voltage, plate-current curve.

current will increase to 10 milliamperes; but on the negative half-cycle there will be — 4 volts on the grid and the plate current will decrease to 6 milliamperes. Thus, a 1-volt a. c. signal will cause a plate current change of 4 milliamperes in this tube. This can be demonstrated graphically by showing the a. c. voltage wave form on the grid-voltage scale of the $E_g—I_p$ characteristic curve, and plotting the plate-current wave form on the plate-current scale of the graph (fig. 61).

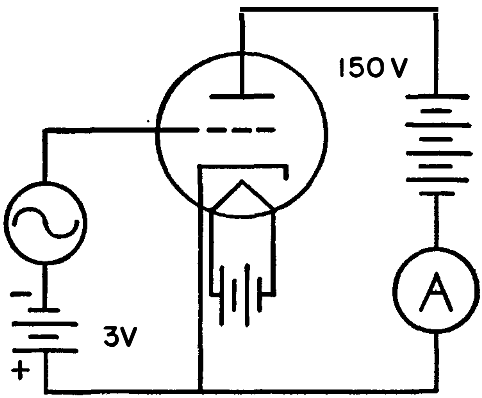


Figure 60.—Triode with an a. c. signal on the grid.

An examination of figure 61 will show that the wave form of the plate-current variation is an exact reproduction of the wave form of the a. c. voltage applied to the tube. By carrying this process further, it can be shown that if the negative bias is increased to 5 volts, so that the grid voltage varies from — 4 to — 6 volts over the a. c. cycle, the plate-current change will vary from 3 to 6 milliamperes, showing a total change of only 3 milliampheres. If the negative bias voltage is increased to 9 volts, so that the grid voltage varies from — 8 to — 10 volts over the a. c. cycle, then the plate-current change will be only 1 milliampere. From this it can be seen that if the negative bias is increased, there is a resultant decrease in the plate current change for a given signal input. This method of controlling the output of a tube by varying the bias voltage is often used as a means of

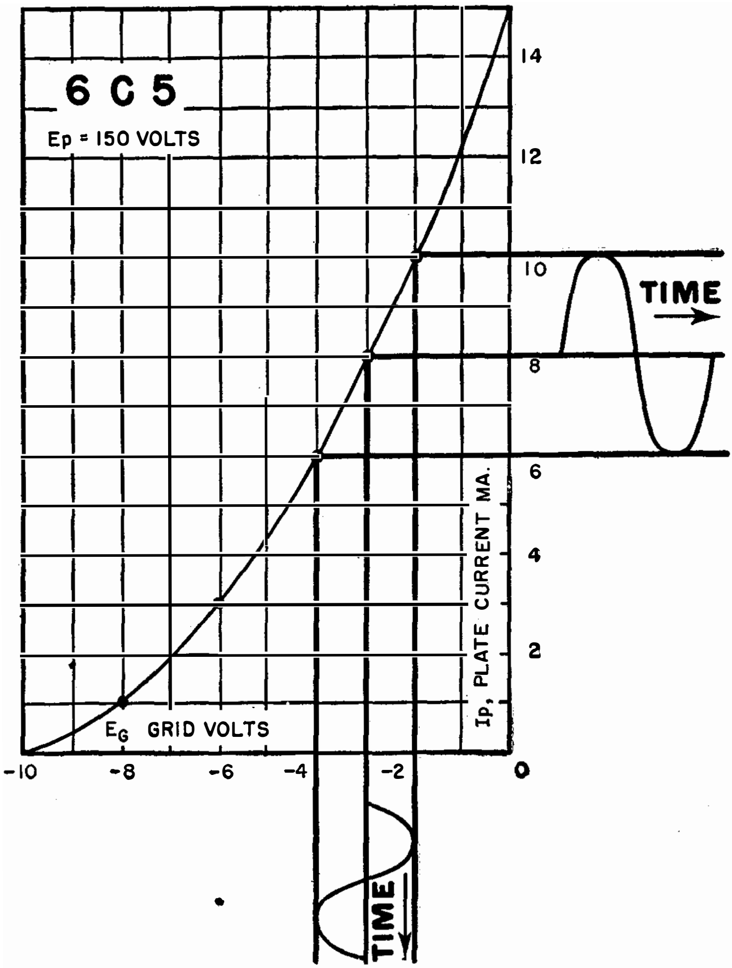


Figure 61.—Plate-current wave form resulting from an a. c. grid voltage.

volume control, as will be shown later in the study of radio receivers. It should be noted, however, that if the grid voltage is increased to too high a negative value (fig. 62a), there is noticeable distortion of the output plate-

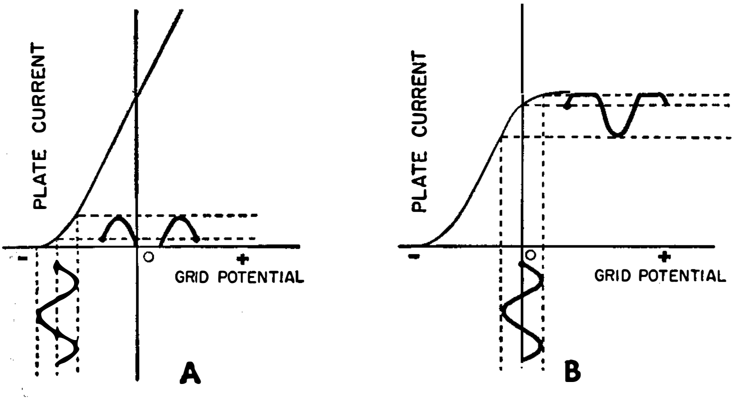


Figure 62.—Distortion due to high grid bias and low cathode temperature.

current wave. Distortion also results if the cathode temperature is lowered to such a degree that the emission is insufficient (fig. 62b). A distorted output is generally, but not always, objectionable.

TRIODE CIRCUITS; PLATE LOADS

In order to make use of the variations in the plate current of a triode due to variations in grid voltage, some sort of a device must be present in the plate circuit of the tube to act as a load. This plate load can be a resistor, an inductor, or a tuned circuit.

A typical triode circuit with a resistor used as a plate load is shown in figure 63. If the tube in this circuit is biased at — 3 volts and the applied a. c. signal voltage to the grid is 1 volt, the plate-current variation of 4 milliamperes will produce a voltage variation of 40 volts across the 10,000-ohm resistor. On the positive half-cycles, the negative voltage of 2 volts applied to the grid causes a current flow of 10 milliamperes through the

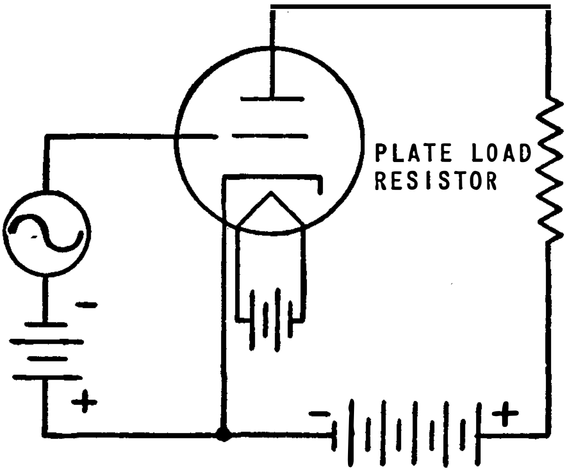


Figure 63.—Triode using a resistor as a plate load.

plate-load resistor, thus producing a voltage drop of 100 volts (by Ohm's law). On the negative half-cycles, the negative voltage of 4 volts applied to the grid causes a current flow of 6 milliamperes through the plate-load resistor, and a corresponding voltage drop of 60 volts. The difference between these two voltage drops, or 40 volts, is the voltage variation in the plate circuit produced by the a. c. voltage applied to the grid. Thus it can be seen that a signal voltage change from -1 to $+1$ (or a total change of 2 volts) can produce a voltage change of 40 volts in the plate circuit; in other words, the original (grid) signal voltage has been amplified 20 times. This process is the basis for all vacuum-tube amplification.

The use of a resistor as the plate load of a vacuum tube has one disadvantage: its resistance will reduce the actual d. c. voltage applied to the plate of the tube, and so reduce

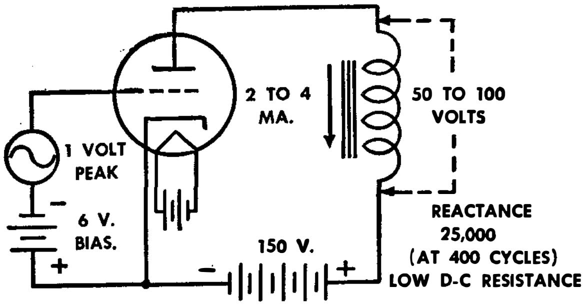


Figure 64.—Triode using an inductor as a plate load.

the amplification of the tube. To overcome this loss in plate voltage, inductors are often used as plate loads of vacuum-tube circuits (fig. 64). By choosing an inductor which has a high value of reactance at the frequency of the alternating current, a large voltage will be built up across the reactance, because of the plate-current changes in the tube. However, the d. c. plate voltage applied to the plate of the tube will be quite high, since the d. c. resistance of an inductor may be very small, and consequently the amplification of the tube will be increased.

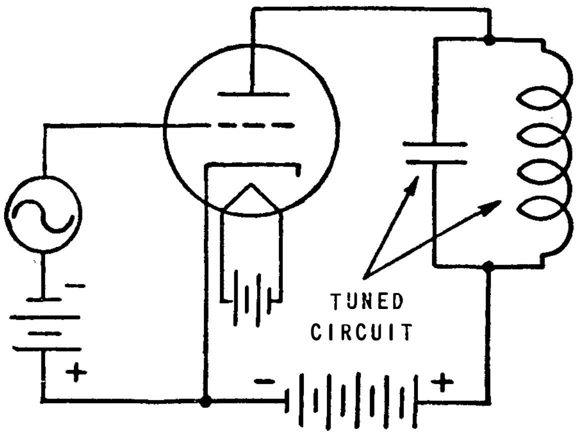


Figure 65.—Triode using a tuned circuit as a plate load.

If it is desired to amplify a signal of a given frequency, a tuned circuit which resonates at this frequency may be used for a plate load (fig. 65). Since the impedance of such a circuit will be very high at the resonant frequency, the signal voltage appearing across the tuned circuit will also be high. By using a tuned circuit as the plate load for a vacuum tube, it is possible to obtain the amplification only at the resonant frequency of the tuned circuit. The circuit of figure 65 is typical of the r. f. amplifier circuits used in radio transmitters.

TRIODE CIRCUITS; BIASING METHODS

There are several different methods of obtaining a negative grid-bias voltage for a triode. The simplest of these is the fixed bias, where a suitable negative voltage is obtained from a fixed source, such as batteries or a rectifier power supply. Examples of this type of bias are shown in figure 57, 60, and 63.

A vacuum-tube circuit can be arranged to produce its own bias, and such a method is known as self-bias. One type of self-biasing, called the cathode-return-resistor bias, is shown in a triode-amplifier circuit in figure 66. In this circuit, the plate current from the battery flows through the cathode resistor on its way through the tube and back to the battery through the plate-load resistor. Since the current is flowing through the cathode resistor toward the cathode, there will be a voltage drop across the resistor which will make the grid negative with respect to the cathode. This is the proper condition for biasing. The convenience of this type of bias is obvious, since it eliminates the need for a separate source of bias voltage. For this reason, cathode-resistor bias is widely used in both transmitters and receivers. Omission of the shunt capacitor, or too small a value of this capacitor, produces degeneration as a result of the variations of grid bias which then accompany the a. c. pulsations of the plate current. This capacitor should have a low reactance at the signal frequency, thus keeping the cathode resistor from dropping the a. c. signal voltage as well as the d. c. plate voltage.

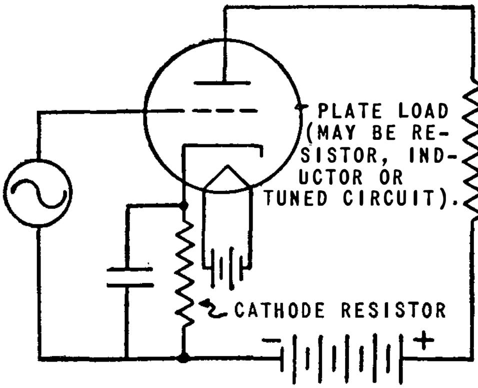


Figure 66.—Triode amplifier circuit with self-bias.

Another form of self-bias is called the grid-leak bias, and is used under conditions where grid current flows. Two examples of this type of bias are shown in figure 67. The bias results from the drop in potential across the resistor when grid current flows on positive a. c. signal swings. This resistor is called a grid-leak. The capacitor across the leak offers a low impedance to alternating current, so that the bias is essentially steady in character and is a function of only the magnitude, or size, of the grid current. A disadvantage of grid-leak bias is that if for any reason the excitation is removed, the bias is removed also, and the plate current may assume dangerous proportions, causing damage to the vacuum tube.

To combine the advantage of grid-leak and battery (or fixed) bias, transmitter amplifiers often use a combination of both types in series. Some types of amplifier tubes are conveniently designed, as regards bias supply, to operate with the grid at cathode potential; these are known as zero-bias tubes.

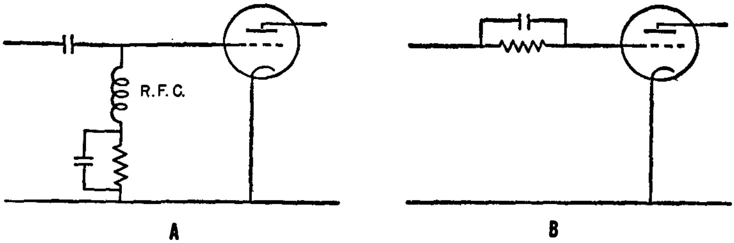


Figure 67.—Grid-leak; bias circuits.

TRIODE CHARACTERISTIC CURVES

There are two general types of characteristic curves for triodes. One is for the case of no load in the plate circuit, and is called the static characteristic curve; the other is for the case of a load in the plate circuit, and is known as the dynamic characteristic curve. Use has already been made of the static curve in figures 59, 61, and 62, where the tube was operating without a plate load. In practice, however, the output of a tube feeds into some sort of load which can be represented by a resistance value (assumed to be the equivalent of the load). This results in dynamic characteristic curves that reflect more accurately the operating conditions of the tube. A comparison of the static and dynamic curves, with the two circuits that are used to obtain each, is due to the fact that the plate-to-cathode potential for no load is constant regardless of the plate current, whereas with a load in the plate circuit the potential across the load (and consequently the plate-to-cathode potential) varies with the current. Assume that the normal operating point is the same for the tube with or without external load; that is, regard the operating point as the point of intersection of the two curves of figure 68c. Without an external load (figure 68a) on a positive swing of signal potential *A* (figure 68c), the plate current rises by an amount *B*. With an external load (figure 68b), the increase in current which follows a positive grid swing is in turn

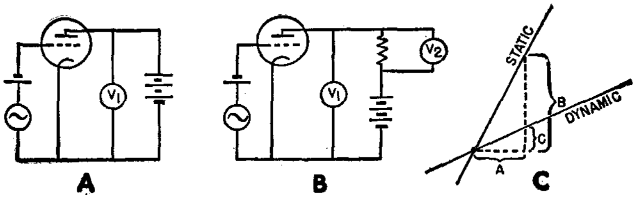


Figure 68.—Triode characteristic curves.

accompanied by a potential drop ($I\ X\ R$) across the load resistor (as read by voltmeter V_2). Thus, the potential available across plate to cathode within the tube (as read by voltmeter V_1) is reduced; and the consequent increase in current C is less than it was under the no load condition. On the negative half-cycle of the signal voltage, the plate current is reduced, and the potential drop across the load is less than it is when no signal is applied. Thus the voltage across the tube rises, so that the available plate-to-cathode potential exceeds the corresponding value under the no load condition. A typical set of static plate-current grid-voltage curves for various plate potentials is shown in figure 69. Many handbooks on vacuum tubes confine the characteristics illustrated to families of curves of the static type.

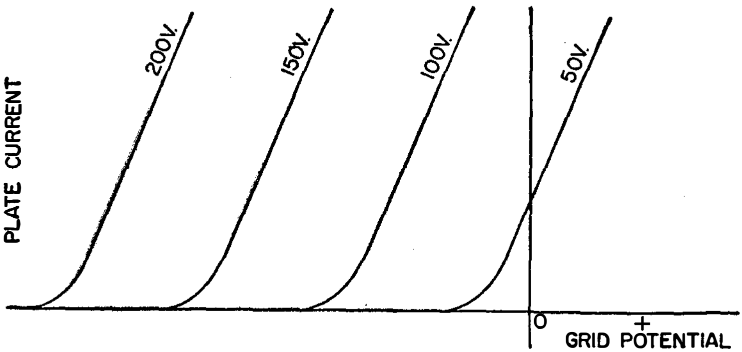


Figure 69.—Plate-current vs. grid-potential curves for triode.

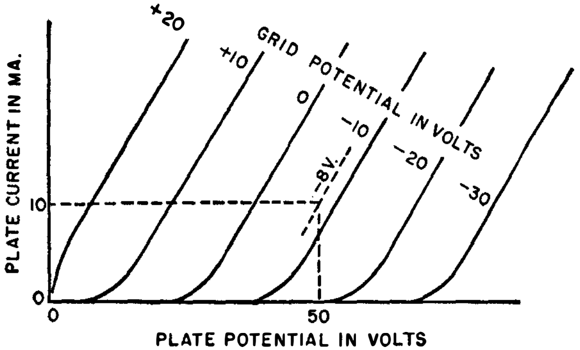


Figure 70.—Plate-current vs. plate-voltage curves for a triode.

Observe from the set of static characteristics curves of figure 70, that of the three quantities, grid potential, plate potential, and plate current, any two will determine the third. Thus, corresponding to a plate current of 10 milliamperes and a plate potential of 50 volts, the required grid potential is − 8 volts. Suppose it is desired to obtain these same relations—plate current, 10 milliamperes; plate potential, 50 volts; and grid potential − 8 volts—with a load resistance of 4,000 ohms. This requires a total plate-supply potential of 50 + [4,000 × (10/1,000)] volts = 90 volts—50 across the tube and 40 across the load resistance. The current in the load resistance follows Ohm's law, that is, the current through the resistance is proportional to the potential across it. This proportionality can be represented by a straight line on the current-voltage graph of figure 71. The line is determined by any two points on it, two convenient points being *P* and *Q*, as in figure 71a. *P* is for a current of 10 milliamperes and a voltage drop across the resistance of 40 volts (50 volts across the tube); *Q* is for zero current and zero drop across the resistance (90 volts across the tube). If *P* is taken as the normal operating point, the grid swing due to an impressed signal voltage will cause variations along this load line in both directions from *P*. Corresponding to an instantaneous grid potential of 10 volts, the plate current, plate voltage, and voltage across the load can be found by following the 10-volt characteristic to where it intersects the load line. From the curves of figure 71b, this yields 16 milliamperes plate current, 25 volts plate potential, and 90 — 25 = 65 volts drop across the load. The family of plate-current, plate-potential curves is thus useful in determining the limitations of a particular tube under various operating conditions. A particular tube can be selected to fit certain circuit constants, or vice versa, with the aid of the information contained in the vacuum-tube characteristics.

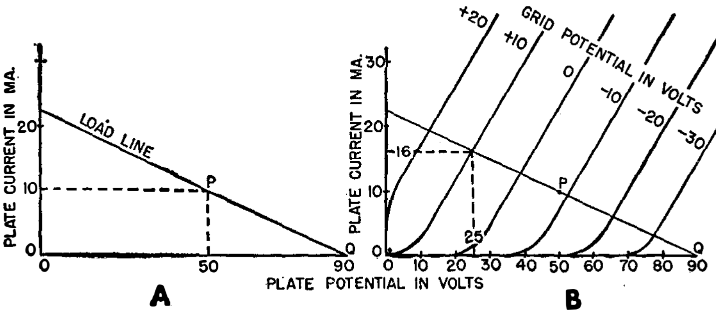


Figure 71.—Load line for a triode.

SPECIAL CHARACTERISTICS OF VACUUM TUBES

Since many different types of vacuum tubes are used in modern radio circuits, it is important to have different means of classifying these tubes according to the performance which may be expected of them. Among these characteristics, as they are called, are the amplification factor, the mutual conductance, and the plate resistance of the tube.

The amplification factor μ, or mu, of a tube is the ratio of the plate-voltage change and the grid-voltage change required to produce the same plate-current change in the tube. For example, if the plate voltage of a tube must be increased by 20 volts in order to increase the plate current as much as would a 1-volt change of grid voltage, the tube has an amplification factor of 20. The amplification factor of a tube is stated for a given set of operating conditions, such as grid-bias voltage, plate voltage, etc., since the amplification factor will change if these conditions are changed. The amplification factor of a tube gives a theoretical approximation of the maximum voltage amplification which can be expected from the tube under given operating conditions.

The mutual conductance, or transconductance, of a tube is a characteristic from which the power sensitivity can be estimated, since it determines what plate-current change may be expected from a given grid-voltage change under a given set of operating conditions. Mutual conductance, or transconductance, is the ratio of a small change in plate current to the change in grid voltage producing it. It is measured in mhos, which is simply the word ohm spelled backwards, with an "s" added. For example, if a grid-voltage change of 1 volt produces a plate-current change of 1 ampere in a given tube under certain operating conditions, the tube will have a mutual conductance of 1 mho. But since very few tubes will stand a plate-current flow of 1 ampere (receiving tubes draw only a few milliamperes of plate current), it is more convenient to rate mutual conductance in micromhos (or millionths of a mho). Thus, if a tube has a mutual conductance of 5,000 micromhos, a 1-volt change in grid voltage will produce a 5 milliampere change in plate current.

The plate resistance of a tube is simply the resistance between the cathode and plate of the tube to the flow of alternating current. It is the ratio between a small change in plate voltage and the corresponding change in plate current. For example, if a 10-volt change in plate voltage produces a 1-milliampere change in plate current, the plate resistance of the tube is 10,000 ohms.

INTERELECTRODE CAPACITANCE

The inherent capacitance between grid and plate elements of a triode is of sufficient importance at high frequencies to require special consideration in radio circuits. Where this capacitance is undesirable, it can be counteracted by introducing a neutralizing circuit which presents r. f. potentials equal in magnitude but opposite in phase to those occurring across the interelectrode capacitance, with the result that the effects of the interelectrode capacitance are nullified. The extra circuit complications can generally be avoided by the use of tetrodes or pentodes, 4- and 5-element tubes, respectively, which are particularly designed to have low interelectrode capacitance. The grid-plate capacitance of an ordinary receiving triode runs about 3 micromicrofarads. This represents a capacitive reactance of 53,000 ohms at 1 megacycle and only 530 ohms at 100 megacycles. Tetrodes and pentodes offer corresponding reactances of about 16,000,000 ohms at 1 megacycle and 160,000 ohms at 100 megacycles.

TETRODE

In an effort to reduce the grid-plate capacitance within the tube a fourth element was added to the conventional triode. This fourth element is called a screen grid, and is placed between the grid and the plate of the tube. A typical screen grid or tetrode (4-element) tube connected in a circuit is shown in figure 72. Observe the changes in this circuit due to the addition of the screen grid. Notice that the screen grid is operated at a positive voltage somewhat lower than that applied to the plate. Since it is operated at a positive voltage, the screen assists the plate in attracting electrons from the cathode. Some of these electrons will be attracted to this grid by the positive voltage on it, thus causing screen current to flow in the circuit. However, since the construction of the screen grid is similar to that of the control grid, most of the electrons will pass through the spaces between its wires on to the plate, because of the attraction of the higher positive voltage on the plate. Since the screen grid is bypassed to the negative side of the circuit (bypassed to ground) by a screen bypass capacitor having a small reactance at the signal frequency, it acts as a shield or screen between the grid and the plate, and thus effectively reduces the capacitance between these two electrodes.

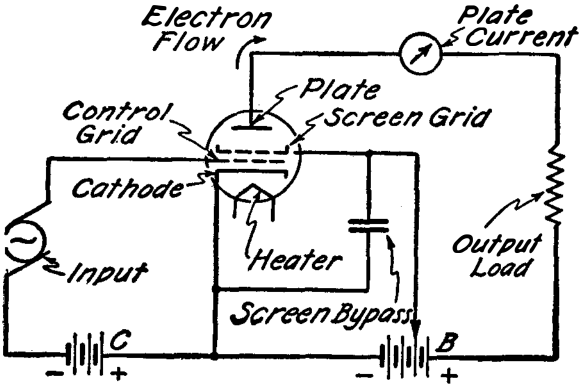


Figure 72.—Tetrode amplifier circuit.

If the screen grid in this circuit is not operated at a positive voltage, but is connected to the cathode, it will have a controlling effect on the electron flow, similar to that of the control grid of the tube, thus reducing the plate-current flow to a value too small for satisfactory operation. The value of a positive voltage on the screen grid of a tetrode will determine to a large extent the maximum value of current which will flow in the plate circuit. Thus, improper screen voltages can cause faulty operation in tetrode amplifier circuits.

The tetrode has several advantages over the triode, in addition to its greatly reduced grid-plate capacitance. Among these are a higher amplification factor, and greater power sensitivity. In general, tetrodes can be used for the same purposes as triodes. Since they were developed to overcome the need for neutralization in r. f. amplifier circuits, tetrodes have been widely used in the r. f. amplifier stages of radio receivers and transmitters.

PENTODE

Although the tetrode would seem to be an ideal tube, since it overcomes the disadvantages of the higher grid-plate capacitance of the triode and, at the same time, is capable of providing higher amplification in a circuit than is the triode, the effect known as secondary emission limits its application to a great extent. The pentode, or 5-element tube, was developed to overcome the effect of secondary emission. If a tetrode is operated at fairly high plate and screen voltages, and large values of signal voltage are applied to its control grid, the electrons strike the plate with sufficient force to knock loose other electrons already on the surface of the plate. These other electrons, known as secondary electrons, are attracted by the positive voltage on the screen grid. When secondary emission occurs, the screen gets more than its share of the available electrons, while the number reaching the plate is greatly reduced. Thus, the screen current will increase while the plate current will decrease, causing a reduction in the amplification of the tube and distortion in its output.

If a third grid is placed between the screen grid and the plate of the tetrode, and is connected to the cathode so that it will have the same charge as the electrons, it will force any secondary electrons back to the plate, since like charges repel one another. This third grid is called the suppressor grid, since it suppresses the effects of secondary emission by preventing the flow of secondary electrons to the screen. The suppressor grid will not reduce the electron flow to the plate, even though it is operated at a negative potential. This is because it is placed so close to the plate that the attraction of the positive voltage on the plate is much greater than any tendency on the part of the suppressor grid to repel the electrons.

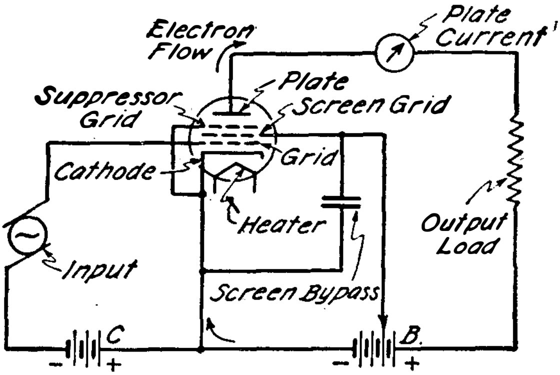


Figure 73.—Pentode amplifier circuit.

A pentode used with a typical amplifier circuit is shown in figure 73. Note that the only difference between this circuit and the tetrode amplifier circuit of figure 74 is the addition of the suppressor grid. Both the cathode and the suppressor grid are at the same potential.

The construction of a typical pentode power-amplifier tube is shown in figure 74. Such a tube is suitable for use in the power-output stages of radio receivers.

VARIABLE-MU TUBE

The amplification of a tube is controlled by varying the bias voltage applied to the grid, but normally the range of this control is limited by the value of cut-off bias for the tube. It is most desirable in the r. f. amplifiers of receivers, the gain of which is controlled by automatic volume control, to be able to vary the amplification over

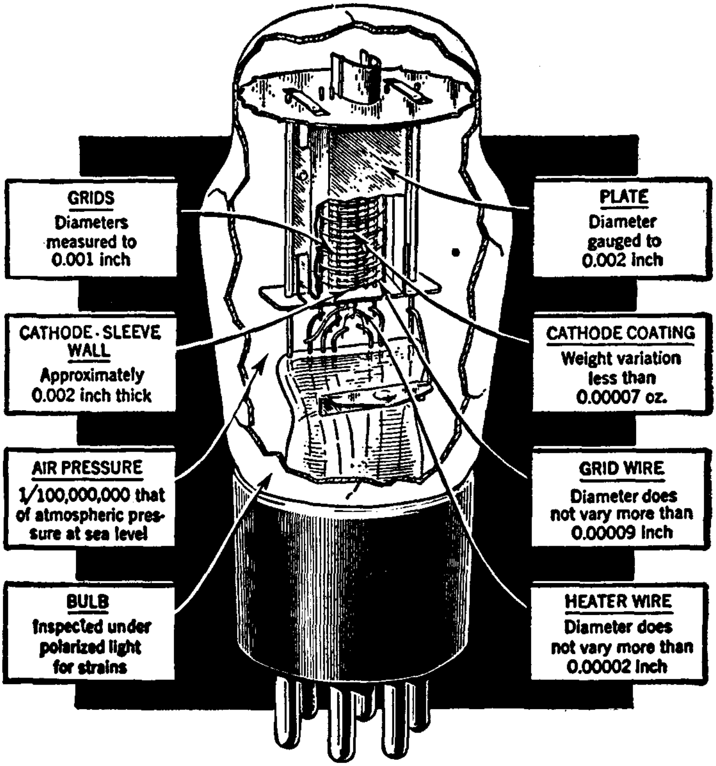


Figure 74.—Typical pentode.

a much wider range, so that large values of signal voltage (strong signals) may be handled. To permit this increased range of gain control, the variable-mu tube has been developed. This type of tube is also known by several other names, two of which are supercontrol and remote cut-off. The only difference in construction between variable-mu tubes and normal, or sharp cut-off, types, is the spacing of the turns of the grid. In sharp cut-off tubes, the turns of the grid wire are equally spaced, while in remote cut-off types the grid turns are closely spaced on both ends and widely spaced in the center. When small negative voltages are applied to the grid of a variable-mu tube, the electrons will flow through all the spaces in the grid. As the negative voltage is increased, however, the electrons will no longer be able to pass through the narrow spaces on the ends of the grid structure, though they will still be able to pass through the relatively greater spaces at the center of the grid. A much greater value of negative voltage will thus be required to cut off the plate-current flow in this type of tube. This remote cut-off tube is so named because the cut-off bias value is greater than the value required to cut off plate-current flow in tubes of evenly spaced grid turns.

Figure 75 shows the E_g—I_p curves for a typical sharp cut-off pentode and a typical remote cut-off pentode on the same graph. Note that the cut-off bias for the tube with the uniformly spaced grid is —6 volts. Thus, the range of gain control which can be effected by grid-bias variation, and the maximum value of signal voltage which can be applied to the grid, are both limited. But the curve for the supercontrol pentode shows that plate current still flows even at a grid bias of — 24 volts. Thus, by the use of a variable-mu tube, both the range of gain control by grid-bias variation and the value of signal voltage which can be handled by the grid have been extended several times.

Variable-mu pentodes are used in the r. f. amplifier stages of practically all modern radio receivers. They are not generally used in a. f. amplifiers, however, because of extreme curvature, or nonlinearity, of their E_g—I_p curves, which would result in distortion of the output voltage when large signal voltages were applied to their grids.

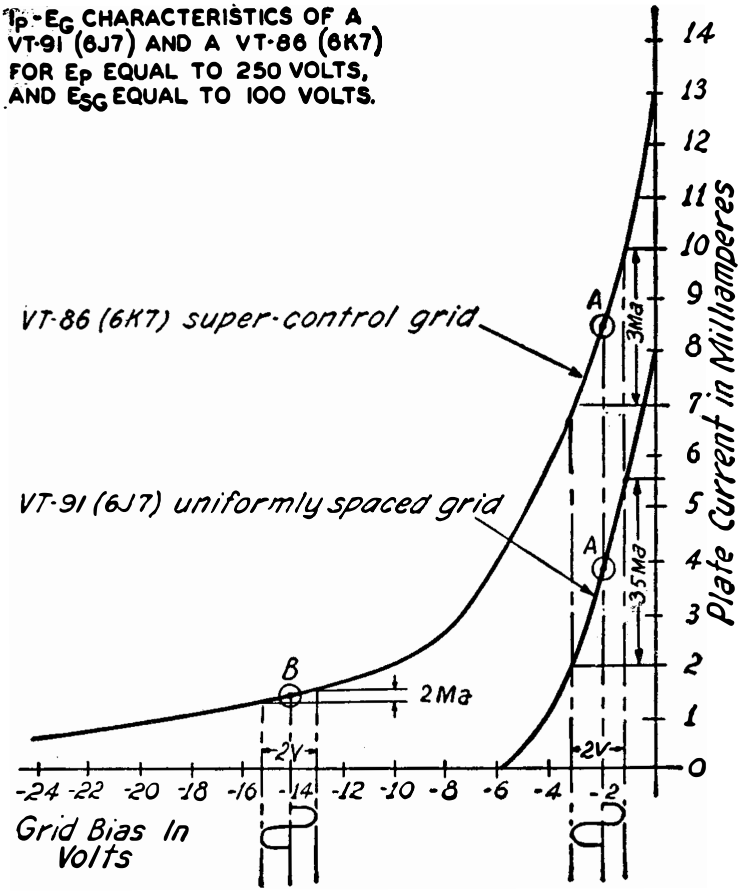


Figure 75.—Comparison between a sharp cut-off pentode and a remote cut-off pentode.

BEAM-POWER TUBE

In recent years a new type of power-amplifier tube has been developed. Compared with other tetrode and pentode power-amplifier tubes, this tube has the advantages of higher power output, higher power sensitivity, and higher efficiency. This type of tube is called the beam-power tube, since by its construction the electrons are caused to flow in a concentrated beam from the cathode, through the grids, to the plate. The only difference in construction between the beam-power tube and normal tetrodes and pentodes is that the spaces between the

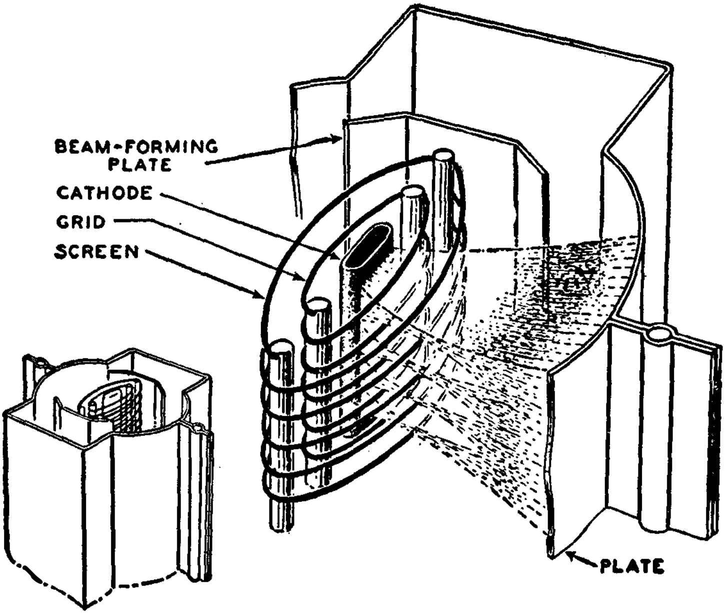


Figure 76.—Internal structure of a beam-power tube.

turns of the several grids are lined up and two beam-forming plates are provided. Figure 76 shows the internal construction of a beam-power tetrode. Since the spaces between the turns of the grids are lined up, fewer electrons will strike the screen grid. The screen current will therefore be decreased, while the plate current will be increased. Since the power output of a circuit is proportional to the value of plate current flowing through the load, the power output will thus be increased. The two beam-forming plates are usually connected to the cathode and, having the same charge as the electrons, cause them to flow in a beam from the cathode, through the grids, to the plate. The placement of the beam-forming plates is such that it forces the electrons to flow through the desired portions of the grids, and prevents them from striking the wires which support the grids. Thus, by

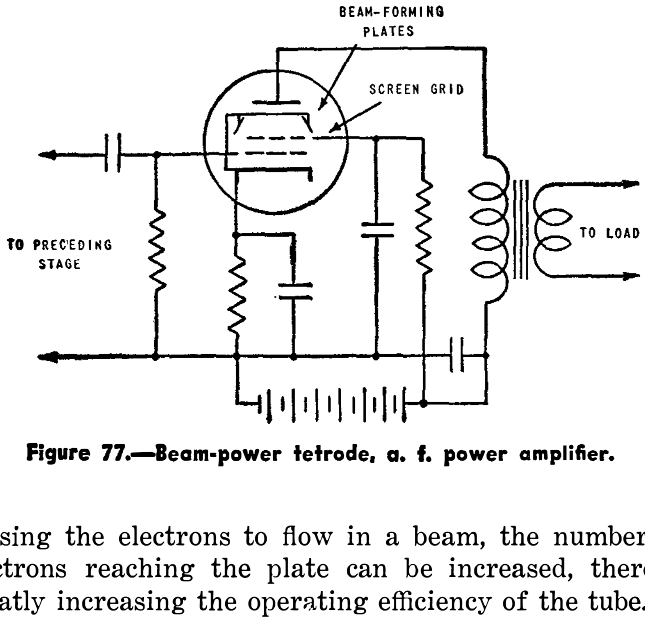


Figure 77.—Beam-power tetrode, a. f. power amplifier.

causing the electrons to flow in a beam, the number of electrons reaching the plate can be increased, thereby greatly increasing the operating efficiency of the tube.

Figure 77 illustrates an a. f. power-amplifier circuit using a beam-power tetrode. Notice that in this case the beam-forming plates are connected to the cathode inside the tube.

A beam-power tube operated at the same voltages as a normal tetrode or pentode type will provide more power output for a given value of signal (input) voltage than the latter, and have a much higher plate-circuit efficiency. Both beam tetrodes and beam pentodes are used in radio receivers and transmitters. In beam tetrodes, the effect of secondary emission is reduced to a minimum by the action of the beam, and the replacement of the beam-forming plates. Beam-power tubes are widely used as r. f. and a. f. amplifiers in radio transmitters, and as output a. f. amplifiers in radio receivers.

MULTIELEMENT TUBES

In addition to the diodes, triodes, tetrodes, and pentodes which have been studied, there are many special types of vacuum tubes used in radio circuits; a large number of types are used which combine the electrodes of two or more tubes in one envelope. These complex tubes are usually named according to the equivalent single-tube types of which they are composed. Thus a twin triode contains the electrodes for two triodes in one envelope. Other complex tubes are diode triodes, diode pentodes, triode pentodes. One complex type has recently been introduced which combines the functions of three tubes within one envelope, namely, a diode, a triode, and a power-output pentode. All of these tubes, however complex, follow the basic rules for tube operation. To understand the operation of any one of them in a circuit it is only necessary to consider the effect of the various electrodes on the flow of electrons within the tube.

The pentagrid-converter tube is a special type which has five grids, and is used in a certain stage of the superheterodyne receiver to take the place of two separate vacuum tubes. The pentagrid-converter tube is used for frequency conversion.

The duplex-diode triode and the duplex-diode pentode are two popular types of receiver tubes. In receiver circuits, one of the diodes is used together with the cathode as a diode-detector circuit, while the other diode is used together with the cathode to rectify the signal voltage in order to produce a source of automatic volume control. The triode or pentode section of such tubes is used as an a. f. amplifier.

DIRECTLY AND INDIRECTLY HEATED CATHODES

A cathode which is in the form of a filament directly heated by passing a current through it has the disadvantage of introducing a ripple in the plate current when alternating current is used for heating. The ripple is most objectionable if the plate and grid returns are made to one end of the filament. In figure 78 the resistor *AB*

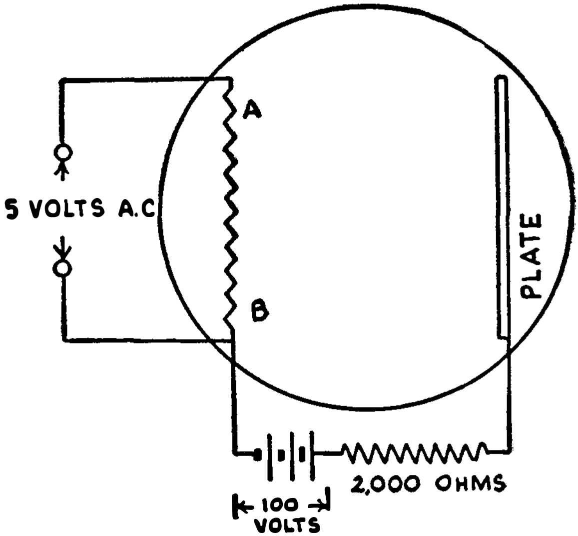


Figure 78.—Directly heated cathode.

represents a filament which is heated by applying 5 volts of alternating current across it. When no current flows through the tube, the plate is maintained at a potential of 100 volts above that of point *B*. For a 5-milliampere steady plate current, the potential across the tube from *B* to the plate is always $100 - [2{,}000 \times \frac{5}{1{,}000}] = 90$ volts; whereas the potential from *A* to the plate varies from 85 to 95 volts, depending upon the potential of point *A* relative to point *B*. The total plate current rises and falls at the frequency of the filament current. This condition is remedied to a large extent by connecting the grid and plate returns to the electrical center of the filament, as in figure 79a or b. But even with a center-return arrangement, with a 60-cycle filament current, there is still present a 120-cycle modulation of the plate current. This double-frequency ripple arises from the effects in the plate current provided by the intermittent rise and fall of the filament temperature, the voltage drop in the filament, and the alternating magnetic field set up by the filament current. Temperature fluctuations in the filament are ordinarily negligible. The magnetic field about the filament serves to deflect the electrons from their normal paths; and, in effect, serves to reduce the plate current. The resulting plate current is largest when the

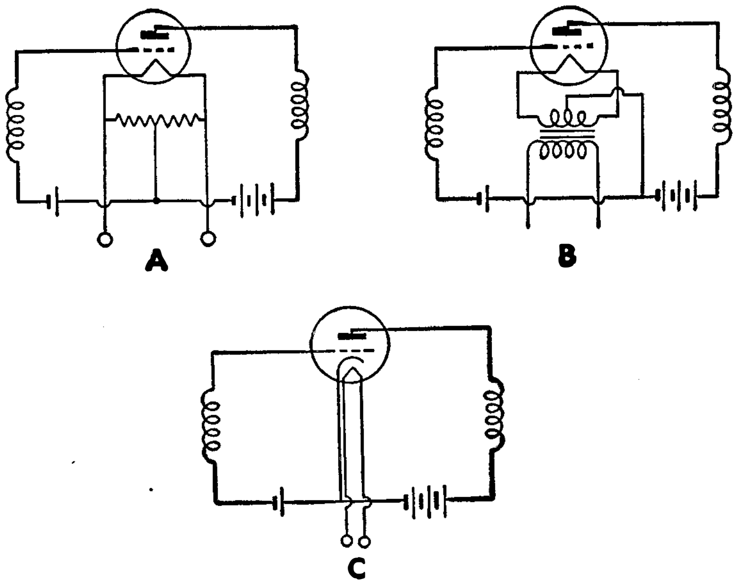


Figure 79.—Methods of utilizing a. c. filament supply.

heating current is zero, that is, at intervals which occur at double the heating current frequency. With a voltage drop in the filament, the space current from the negative half of the filament exceeds that from the positive half, because of the manner in which space current varies with the electrostatic field across the tube. (Space current varies as the three-halves power of the plate potential.) The result is that each time the current is at a maximum in either direction in the filament, that is, at a frequency which is double the heating-current frequency, the space current is slightly greater than its value during those instants when the current through the filament is zero and the potential of the filament is uniform.

In transmitting tubes and in the power stages of a receiver the signal currents are large, and the double-frequency ripple current is negligible in comparison. However, in all other receiver tubes, indirectly heated cathodes (fig. 79c) are necessary wherever a. c. filament operation is desired. An indirectly heated cathode is formed by a metallic sleeve closely surrounding a heated filament and electrically insulated from the filament. The cathode is heated by radiation from the filament. Such an emitter is sometimes referred to as an equipotential cathode, since all parts of it are at the same potential.

GAS TUBES

If a tube containing an anode and a cathode is evacuated and then a small, carefully regulated amount of a certain gas is put back into it, the tube is called a gas-filled or gas tube. If the cathode is heated, indirectly as in most vacuum tubes, the tube is a HOT cathode gas tube; if the cathode is not heated, the tube is called COLD cathode gas tube.

If a sufficiently high positive voltage is applied to the anode of a hot cathode gas tube, the electrons boiling out of the cathode are immediately attracted toward the anode. If the attracting positive voltage is high enough, and if there are not too many gas atoms present, these electrons pick up enough speed so that when they do bump into gas atoms on the way toward the anode, they knock out other electrons from these atoms. This in turn leaves the gas atoms positively charged and they, therefore, start moving toward the cathode. Since a large number of electrons are involved right at the start, and since all secondary electrons knocked out of the gas atoms also knock out still more electrons on their way toward the anode, the result is that in an extremely short time there is an abundance of electrons and positively charged atoms between the anode and the cathode. As is commonly stated, the gas becomes ionized. It becomes a good conductor of electric current. The value of the positive potential which is required to produce this ionization is called the IONIZATION or BREAK-DOWN or STRIKING voltage of the tube. These start the process which is, of course, cumulative and results in ionization. Once ionized, the gas will serve as a good conductor of electrons or current in both types of tubes, the difference being that in the hot cathode tube there is a constant supply of electrons coming out of the cathode, while in the cold cathode tube the supply of electrons results from the positively charged gas atoms hitting the negatively charged cathode with sufficient force to knock out the needed amount of electrons.

A third electrode, often called the grid, is sometimes used to control the instant of ionization. As in a vacuum tube, this grid or control electrode is placed in the tube in such a way that it has a greater effect on the electrons than the anode when ionization is getting started. In other words, it is either physically closer to the cathode than the anode is, and can, therefore, start ionization with a smaller positive potential; or it effectively screens the anode from the cathode, thus preventing the anode from attracting the electrons even with a positive potential on it. In either case, the grid can be given the controlling voice in the start of ionization. However, once ionization has occurred, the grid generally loses its control because even though it is made negative with respect to the cathode (in order to try to repel the electrons back toward the anode and stop the current flow), the abundance of positively charged gas atoms right next to the grid neutralizes this negativeness of the grid and the current therefore, continues to flow. It is of course possible to construct a grid in such a way that it can stop the current flow by making its screening of the anode very effective. This can be accomplished for instance, by using a very closely meshed wire gauze for the grid and surrounding the cathode with it completely and applying a relatively high negative potential to it.

Some of the uses to which a gas tube can be put are readily apparent. The tube is in effect an electric switch, which can be closed in an extremely short time and with practically no power by the mere application of a suitable voltage either to its anode, if it is a two-element tube, or to its grid if it is a three-element tube. Once the tube is ionized, a relatively large amount of current can flow through it. If the effect of an intermittent closing and opening of the switch is desired, the current flow, of course, has to be stopped either by opening its circuit or reducing the anode potential of the tube below what is necessary to maintain ionization, or in some cases by grid control. For consistent results on intermittent operation, it is of course necessary to provide enough time between each ionization period completely to deionize the gas in the tube. This time may be anywhere from a few to a thousand microseconds.

Obviously cold cathode tubes require no power except when actually discharging, and thus are useful as standby devices. The cathode is usually much larger in area than the anode, and as a result, a gas tube will pass current in one direction more readily than in the other. For this reason such tubes are sometimes used as rectifiers.

GAS TUBE AS A VOLTAGE REGULATOR

It is a characteristic of gas tubes that they will maintain a constant differencce in potential between electrodes over a wide range of current values. This means that an increase in current flow is accompanied by a decrease in tube resistance, with the result that the voltage drop across the tube is unchanged. Gas tubes can

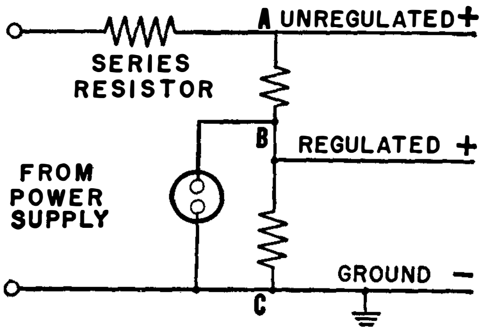


Figure 80.—Gas tube as a voltage regulator.

thus be used as voltage regulator, as shown in figure 80. A practically constant voltage will be maintained across points *BC*.

QUIZ

1. What are the two general types of characteristic curves for triodes?
2. What is the simplest type of vacuum tube?
3. How does the triode differ in construction from the diode?
4. What is the simplest method of obtaining negative grid bias for a triode?
5. What advantages does the beam-power tube have compared with other tetrode and pentode power-amplifier tubes?
6. How many elements does the diode contain? What are they?
7. What are the two types of cathodes, or emitters, used in radio tubes?

8. What makes the diode usable as a rectifier to convert alternating current into direct current?
9. What must be done to convert rectified alternating current into pure direct current?
10. What is the disadvantage of a half-wave rectifier?
11. How does a full-wave rectifier get its name?
12. What does the amplification factor of a tube determine?
13. What is known as the plate resistance of a tube?
14. Between what two elements is the screen grid of a tetrode placed?

CHAPTER 5

RECEIVERS

MORE THAN BASIC

When you began your career as a Navy Radioman, your first step was to qualify as an operator. Then, with your knowledge of radiotelegraph procedure and plenty of practice in sending and receiving, you sat on your first live circuit. During your days as striker and RM3, the care of transmitters and receivers was, for the most part, someone else's responsibility. By working with your leading PO's you learned about routine maintenance and how to correct simple breakdowns of equipment.

As you advance in rating, the need for maintenance know-how becomes increasingly important. In the higher rates, first class and chief, you must have more than a basic knowledge of your equipment. You should be prepared to use meters, conduct materiel tests, and know how to locate and replace defective parts.

This chapter discusses the operation of receiver circuits and special units incorporated in receiving equipment. Emphasis is placed upon testing apparatus, sensitivity measurements, and alinement of tuned circuits. By studying this chapter you can gain a broader knowledge of Navy radio receivers, but in the end, you'll learn more about receivers by working WITH receivers.

VOLTAGE DISTRIBUTION

We can begin our discussion of receivers by considering the power that makes a set operate, and the distribution of this power to circuits within the set. The direct current required at the elements of the vacuum tubes in a radio receiving set are usually taken from a single source. This source must furnish power that will supply the proper positive and negative potentials and maintain good voltage regulation.

The voltage divider regulates the current. It is designed so that a certain amount of the current is not used except to assist in maintaining constant voltage from the various taps. This current is usually referred to as a bleeder current. It flows through the resistance between the lowest positive voltage desired to the common negative return.

The bleeder-current value has a direct influence on the stability of this system. The more current the bleeder resistor carries, the better the stability. With enough current, variation on a particular tap will have little effect on the other taps. The amount of current in the bleeder resistor depends upon the design of the receiver, but is usually about 10 percent of the normal load current. Some systems use considerably more bleeder current, but

10 percent is chosen as a compromise between economy of current and stability of operation.

In the past it was common practice to consider the most negative point in the receiver as being at ground potential, but such is not the case.

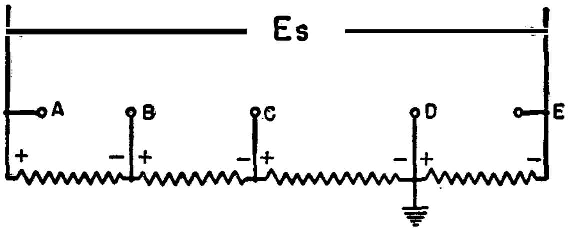


Figure 81.—Simple voltage divider.

A large number of radio systems use arrangements wherein the ground is negative with respect to certain points in the system, and positive with respect to other points. Figure 81 indicates that point (D) is positive in respect to point (E), but negative in respect to point (A). In this case, the voltage developed across resistor *D* could be used as biasing voltage, while the voltage developed across resistors *A, B,* or *C* could be used as other tube element voltages in a circuit having the tube filament or cathode grounded.

Figure 82 shows three vacuum tubes whose plate potentials are taken from taps on a voltage divider network. While tubes 1 and 2 are biased by cathode resistors, tube 3 is biased by the voltage drop obtained from a resistor which is part of the voltage divider network. The ground terminal at tap 4, being a point of common reference, will make the potential developed across resistor R_4 negative, while the potentials developed across the remainder of the divider are positive with respect to ground. In this manner, with the grid of tube 3 connected at the negative return and the cathode grounded, the grid is made negative with respect to the cathode. Tubes 1 and 2 have their cathodes above ground while the grids are at ground potential. This makes the cathode

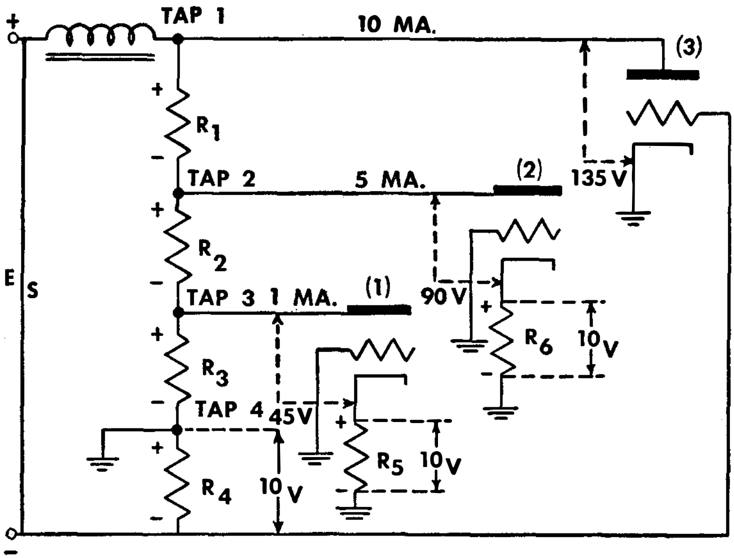


Figure 82.—Simple voltage divider network.

positive with respect to ground, which is the same as making the grid negative with respect to the cathode.

Trace the current through the circuits to establish the polarity of the terminals of the cathode resistors, and to find the amount of current that will flow through each resistor in the network. You can find the total current required by the system by adding the individual tube currents to the percentage of bleeder current desired. Tracing from the negative side of the line you will see that the total current flows through R_4 to the ground. At this point, the current required by each tube branches to the tube emitters. Resistor R_3 carries only the bleeder current. At tap 3, the plate current of tube 1 rejoins the network and you have the bleeder current plus the plate current of tube 1 flowing through resistor R_2. At tap 2, the plate current of tube 2 rejoins the network and you have the bleeder current plus the plate currents of tubes 1 and 2 flowing through resistor R_1. At tap 1, the plate current from tube 3 rejoins, and you have the total current flowing through the filter choke. The element currents of tubes 1 and 2 must flow through the individual cathode resistors which develop the bias voltage across them. Since the direction of electron current flow is from negative to positive, the grounded terminal of each cathode resistor is made negative with respect to the cathode terminal. Taps 1, 2, and 3 are all positive with respect to ground.

Assume you wish to obtain a plate potential of 45 volts at tube 1. It is necessary that tap 3 be taken at a point 55 volts above ground, because all tube element voltages are measured with respect to the emitter. This is due to the 10-volt drop between the emitter (cathode) and ground. Tube 2, having a plate voltage of 90 volts must be tapped at the 100-volt tap. Tube 3, due to the cathode being at ground potential, will be tapped at 135 volts. Now, knowing the current through each resistor and the voltage drop from ground to each tap, you simply apply Ohm's law to determine the value of each resistor.

The distribution of voltage and current throughout a receiver is seldom as simple as that shown in figure 82. A greater number of tubes, plus tubes with multielements which require individual values of voltages together with filter resistors and auxiliary circuits, help to complicate matters. You should thoroughly understand the simple voltage divider, since additional circuits will not alter the fundamental principles of operation.

TUNED RADIO FREQUENCY RECEIVER

The tuned radio frequency receiver, or t. r. f., consists of one or more stages of r. f. amplification, a detector stage, and one or more stages of a. f. amplification. Figure 83 shows a block diagram of a typical t. r. f. receiver. Radio energy waves from a distant transmitter causes an r. f. signal current to flow in the receiving antenna. This r. f. signal is amplified by the r. f. ampli-

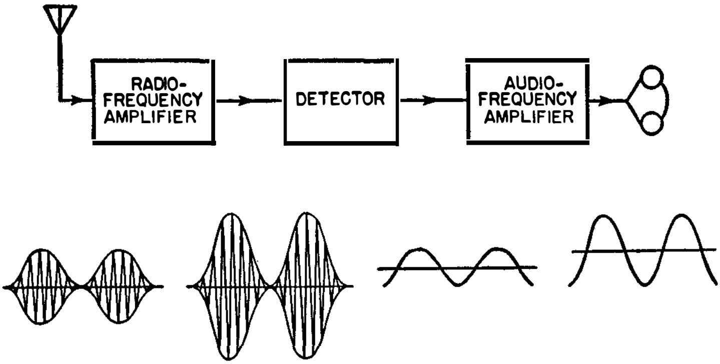


Figure 83.—Signal passing through t. r. f. receiver.

fier stages, and is then detected, or demodulated, by the detector. The resulting a. f. output, from the detector stage, is amplified by the a. f. amplifier stages, and the audible sound is heard in either a loudspeaker or earphones. The wave forms below the block diagram of figure 83 give a comparative indication of the process of converting r. f. signals into intelligible a. f. signals.

R. F. AMPLIFIERS

Tuned r. f. amplifier stages increase the selectivity and the sensitivity of the t. r. f. receiver. The more stages used the greater this increase. Important aspects of the r. f. amplifier are the types of tubes, r. f. transformers, capacitors, and resistors used, and the nature of band spread and special decoupling circuits.

Tetrodes and pentodes are used in r. f. amplifiers. Any tube suitable for voltage amplification may be used. Triodes, which were used at one time, are not as satisfactory because they have a strong tendency to cause undesirable oscillations in r. f. amplifier stages. They also require very careful neutralization (adjustment) to prevent feedback from stage to stage.

The r. f. transformer used in most t. r. f. receivers consists of a primary coil and secondary coil. Most r. f. transformers in use at the present time are of the air-core type. A few special types may be found which use powdered-iron cores when the frequency of operation is not too high. If a receiver is to cover a greater frequency range than one coil and tuning capacitor will permit, the tuning circuits of the receiver must be changed to tune to these additional frequency bands. One system is to use plug-in coils, which may be changed to provide the different tuning ranges required. Another system is to mount the various coils for the different frequencies in the receiver, and bring the leads out to a multicontact rotary switch. This is called BAND SWITCHING and by turning the switch, any desired band can be selected. In both methods the same tuning capacitors are used for all tuning ranges. Both systems of band changing are used in Navy receivers.

Figure 84 shows the basic circuit of a pentode class *A* t. r. f. amplifier. The tuned circuit *L*1*C*1 is coupled to coil *L*, which in this case is the antenna coil, but could be the plate coil of a preceding stage. The secondary coil *L*1 is designed to cover the desired frequency range when tuned by capacitor *C*1 connected across the secondary. Resistor *R*1 and capacitor *C*2 are the cathode bias resistor and cathode bypass capacitor. Capacitor *C*3 is the screen bypass capacitor and *R*2 is the screen voltage-dropping resistor. A second tuned circuit, *L*3*C*5, is coupled to coil *L*2. Coils *L* and *L*1 form the primary and secondary windings of an r. f. transformer. Coils *L*2 and *L*3 also form an r. f. transformer.

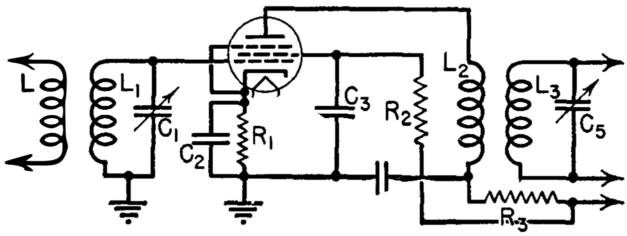


Figure 84.—Radio frequency stage of a t. r. f. receiver.

Most t. r. f. receivers use two or three r. f. stages preceding the detector, with each stage tuned to the same frequency. It is more convenient to have all the tuning capacitors mounted on a common shaft, so all stages can be tuned simultaneously. These are called ganged variable capacitors. In a receiver having two r. f. stages, a three-gang capacitor would be used, with one of its sections tuning each of the three tuned circuits in the receiver. When these tuning circuits are ganged, the coils and the capacitors must be identical. This is necessary since all the circuits must tune to the same frequency at any dial setting. Inaccuracies of the coils and capacitors, and stray circuit capacitances will prevent the circuits from tuning to the same frequency. Thus, there must be some method of compensating for these irregularities. This is provided by connecting small trimmer capacitors across each tuning capacitor. These trimmers may be adjusted with a nonmetallic screw driver or small neutralizing wrench, so that each circuit is tuned exactly to the signal frequency. This process is known as alinement. In practice, these capacitors are adjusted at the h. f. end of the dial, where the plates of the tuning capacitors are slightly meshed and their capacitances are small. The circuits may be properly adjusted at one dial setting, and fail to tune to identical frequencies at other dial settings. In some sets, this is corrected by slotting the end rotor plates of the tuning capacitors, so that any portion of the end plates may be bent closer to or farther away from the stator plates. When all the stages tune to identical frequencies at all dial settings they are said to be tracking, and the maximum gain will be obtained from the receiver. In receivers using band changing, a trimmer for each range is usually mounted on the individual coils. In receivers covering only one band, the trimmers are usually located on the ganged capacitors, one for each section. Alinement and neutralization of t. r. f. receivers will be found later in this chapter.

Resistors used in the r. f. amplifier and in the detector circuits are practically all of the small carbon type. The wattage rating will depend on the voltage drop in the resistor and the current through it.

BAND SPREAD

Band spread is the process of spreading out a small section of the tuning range of a receiver over the entire scale of a separate tuning dial. The purpose of band spread is to assist in separating stations crowded together in a small space on the main tuning dial. There are two types of band spread: electrical and mechanical.

In electrical band spread a small variable capacitor is connected in parallel with the main tuning capacitor in the tuned circuit. The tuning range of the band-spread capacitor is only a fraction of the range of the main tuning capacitor. To increase the amount of band spread, the small capacitor may be tapped down on the coil, so that it tunes only a small portion of the coil. Figure 85 shows two methods of electrical band spread.

In mechanical band spread, the band-spread dial is connected by reduction gears to the main tuning dial, so that one complete rotation of the band-spread dial moves the main tuning dial and capacitor over a small fraction of its range.

When several amplifier stages are operated from a common plate supply, there is a possibility of undesirable oscillations being set up because the plate circuits of the

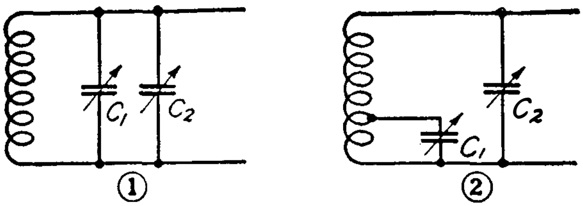


Figure 85.—(1) Parallel capacitor band spread, and (2) tapped-coil band spread.

various stages are coupled together by the common impedance of the plate supply. (See fig. 86 (1).) Note that voltage for both tubes is obtained from a common *B*, or plate, supply. The internal resistance of this common supply is represented by *R*. Any change of plate-current flow in tube 2, such as a signal current, will cause a change of voltage across *R*. This causes a change of the *B* supply voltage to the plate of tube 1, and induces a voltage in *L*1, which is connected to the grid circuit of tube 2. This tube will amplify the change and it will appear across *L*2 as a larger change. It can be seen that a part of a signal from the plate of tube 2 is fed back to the grid circuit of the same tube. This condition may cause unwanted oscillation. Circuits that prevent this condition are called decoupling circuits, and are shown in figure 86 (2). The capacitors *C* and *C*1, together with resistors *R*1 and *R*2, make up the decoupling circuit. The resistors *R*1 and *R*2 offer a high impedance to the signal voltage, while the capacitors *C* and *C*1 bypass the signal voltage around the *B* supply. A choke coil can be used instead of the resistors *R*1 and *R*2. The bypass capacitors for the cathode, screen-grid, and plate circuits in t. r. f. receivers are usually paper capacitors, except in circuits that operate on extremely high frequencies and in receivers designed for special applications, such as aircraft receivers. In most receivers the paper capacitors are enclosed in metal cases, two or three capacitors often

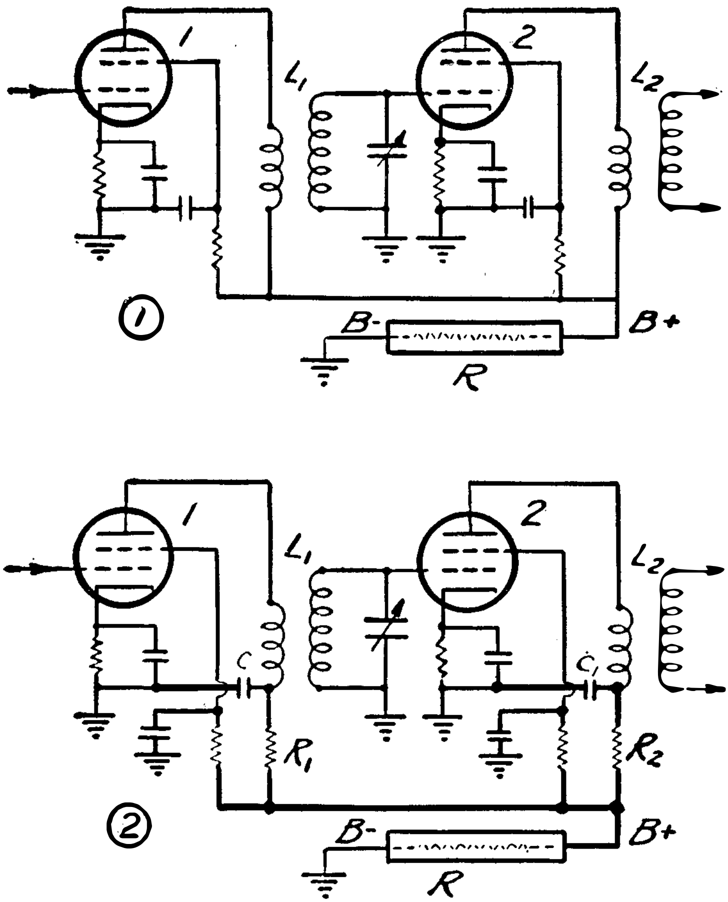


Figure 86.—Radio frequency amplifier, without and with decoupling circuit.

being grouped together in one can. Where one connection to each capacitor is connected to ground in the circuit, the metal can itself is often the common-ground terminal. In some cases, a single terminal may be provided as a common ground for all capacitors in the can.

DETECTOR CIRCUITS

Since the voltage amplification of the r. f. amplifiers of the modern t. r. f. receiver is relatively great, the signal voltage fed to the detector stage is large. As the grid-leak detector is easily overloaded by such large voltages, it is rarely used in present-day t.r.f. receivers. The two most widely used detector circuits are the diode detector and the power detector.

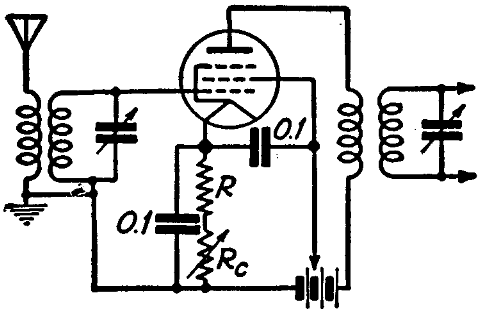


Figure 87.—Grid-bias volume control.

VOLUME CONTROL

Since all signals will not arrive at the receiving antenna with equal intensity, a gain or volume control is provided so that the volume of the signal received can be varied. The most commonly used methods of doing this are shown in figures 87 and 88. In figure 87, the control is in the grid-bias circuit of a variable-*mu* pentode r. f. amplifier. You'll recall that varying the bias of variable-*mu* tubes causes the amplification factor to increase or decrease, thus controlling the gain of the stage.

Resistor *R* provides the proper bias for maximum gain when *Rc* is adjusted to zero resistance. The bias voltages of all r. f. amplifier tubes in the receiver are usually controlled when this method is used. Another method, illustrated in figure 88, controls the amount of a. f. voltage applied to the grid of the a. f. amplifier from the diode detector.

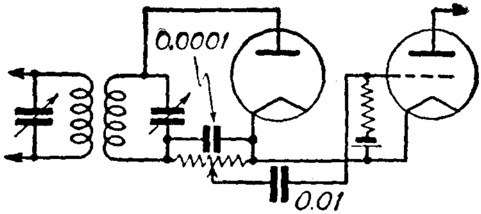


Figure 88.—Detector output volume control.

Once the volume or gain control of a receiver has been set, the output should remain constant, regardless of the strength of the incoming signal. The development of the variable-*mu* pentode tube makes this possible, since the amplification of the tube may be controlled by the grid-bias voltage. Then all that is needed for automatic volume control is a source of voltage which becomes more negative as the signal strength becomes greater. If this voltage is applied as bias to the grids of the variable-*mu* r. f. amplifier stages, the grids will become more negative as the signals grow stronger. This will reduce amplification, thus tending to keep the output of the receiver at a constant level. The load resistor of the diode detector is an excellent source of this type voltage, because the rectified signal voltage will increase and decrease with the signal strength. A typical detector diode with an (a. v. c.) circuit is shown in figure 89. The signal is rectified by the diode detector, and the rectified current flowing through the load resistor causes a voltage drop across the resistor, as indicated in figure 89. The negative voltage developed is impressed on the grids of the variable-*mu* tubes in the

r. f. stages. Any increase in signal strength results in a greater voltage drop and an increase in negative bias to the amplifiers. This results in a decrease in signal strength to the detector. This decrease reduces the amount of negative bias on the amplifier tubes, increases

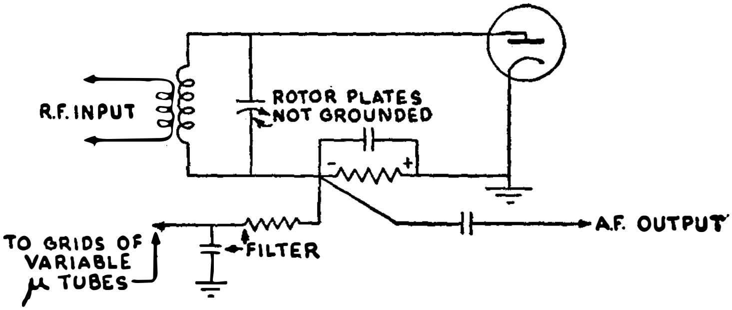


Figure 89.—Automatic volume-control circuit.

gain in those stages, and the input to the detector increases. The filter circuit removes the a. f. component of the signal, and only the slower variations caused by fading or change in position of the receiver, effect the gain of the amplifier stages. Automatic volume control is particularly desirable for mobile receivers where the signal strength is changeable due to the receiver being moved.

The variable-*mu* tube is designed to operate with a minimum bias of about 3 volts. This minimum bias is usually provided by a cathode resistor, and the a. v. c. bias is in series with it. A disadvantage of ordinary automatic volume control is that even the weakest signal slightly reduces amplification. An adaptation which avoids this condition is shown in figure 90 and is referred to as delayed automatic volume control. In this particular circuit the a. v. c. diode is separate from the detector diode, and both are housed in the same vacuum tube with a pentode amplifier. The tube is called a duplex-diode pentode. Part of the energy fed to the plate of the detector diode is capacitively coupled to the a. v. c. diode and the plate of this diode is maintained at a negative voltage by a cathode-biasing resistor *R*. This keeps it from rectifying and producing the a. v. c. voltage until the peak voltage

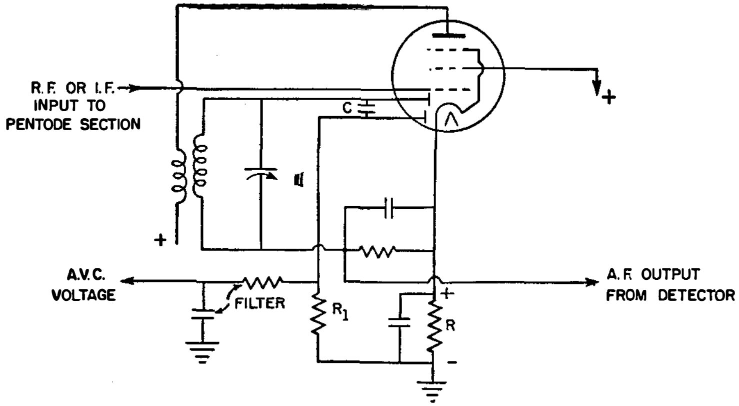


Figure 90.—Delayed automatic volume control.

coupled to it through *C* counterbalances the negative voltage of the a. v. c. diode. For very weak signals, which do not produce enough voltage on the plate of the a. v. c. diode to overcome the existing negative potential, no a. v. c. voltage is developed. Thus, the sensitivity of the receiver remains the same as if automatic volume control were not being used. On the other hand, when normal strength signals are being received, which do not need maximum sensitivity of the set, enough voltage will be coupled to the a. v. c. diode to overcome the small negative plate potential and produce an a. v. c. voltage drop across resistor *R*. This voltage has the a. f. and r. f. components filtered from it and is applied to the grids of the variable-*mu* tubes, as in the ordinary a. v. c. circuit.

Duplex-diode triode and duplex-diode pentode tubes are widely used to supply a. v. c. voltages. In addition, the second diode in these tubes is used, together with the cathode, as a diode-detector circuit, and the triode or pentode section is used as a separate a. f. amplifier. Thus, by the use of such multielement tubes, the functions of detection, a. v. c. voltage rectification, and amplification, are combined within a single tube.

A. F. AMPLIFIERS

Since the signal output of a detector stage in a t. r. f. receiver is low or weak, it is usual to have at least one stage of a. f. amplification. The output of this first a. f. amplifier may be further amplified if necessary, depending on the requirements of the receiver. A headset may require no further amplification after the first a. f. stage, while a large loudspeaker may require several additional stages of a. f. amplification.

SHIELDING

To prevent coupling between two circuits, metal shields are used: iron for a. f. circuits, and copper or aluminum for r. f. circuits. All shields should be grounded to the chassis of the receiver, which is the common ground for all connections in the set. Since shielding changes the inductance of a coil, it changes the resonance frequency to which it responds. It is necessary, therefore, to make adjustments in radio sets with the shields in place.

CIRCUIT OF A T. R. F. RECEIVER

The complete circuit diagram of a five-tube tuned r. f. receiver is shown in figure 91. This receiver uses three pentode r. f. amplifier stages, a diode-detector stage, and a pentode a. f. amplifier stage energizing a loudspeaker. The *A* supply (heater voltage) and *B* supply (plate and screen voltages) are furnished the vacuum tubes by batteries when the double-pole single-throw switch is closed. The dotted lines connecting the four tuning capac-

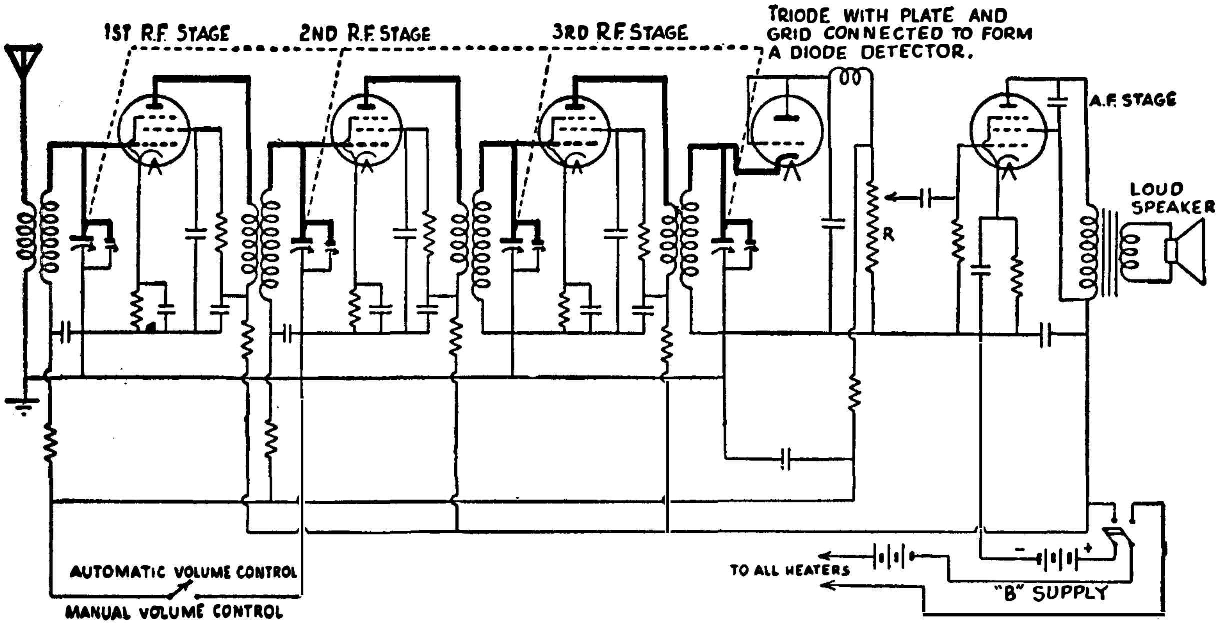


Figure 91.—T. r. f. receiver with automatic volume control.

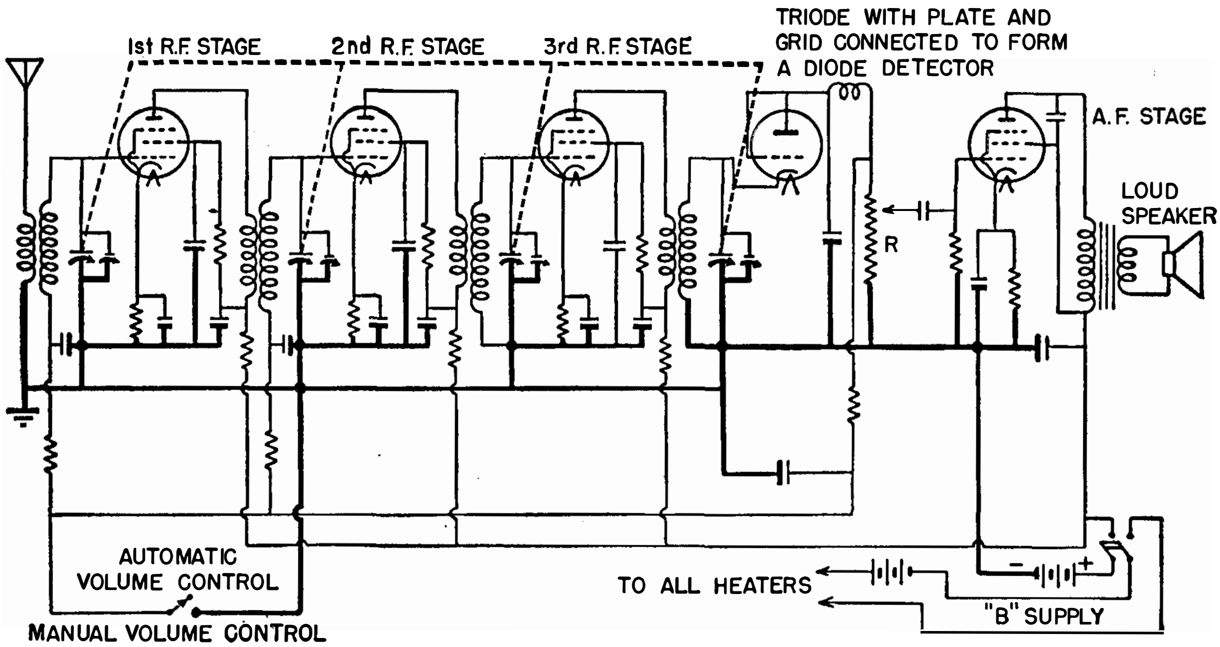


Figure 92.—T. r. f. receiver. Grounded potential elements denoted by heavy lines.

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itors indicate that these capacitors are ganged. A small trimmer capacitor is connected in parallel with each section of the ganged tuning capacitor for proper alinement of the receiver. These small trimmers compensate for inequalities in any of the circuit constants. The detector stage is considered a diode, since the grid and the plate of the triode are connected together. Figures 92 to 96 will show you the same receiver diagram with various circuits emphasized to facilitate study.

In figure 92, all parts of the t. r. f. receiver at ground, or chassis, potential are denoted by heavy lines. All points on the heavy (ground) line will be at the same potential, which is considered to be zero volts with respect to the rest of the receiver circuit. All voltages in the receiver are compared to this ground potential.

In figure 94, the high voltage d. c. plate supply is shown by heavy lines. When the switch is closed, the four pentodes receive the high positive plate voltage necessary for their action as amplifiers. The diode, operating as a detector, does not require d. c. plate voltage. Note the decoupling resistors in the plate leads of the first three pentodes.

In figure 95, the complete detector circuit is shown in heavy lines. The tube used in this stage is considered a diode. The grid and the plate of the triode are connected, or tied together, resulting in a two-element tube, or diode. The rectified or detected signal is taken from a portion of the potentiometer *R* and coupled through a capacitor to the grid of the pentode a. f. amplifier.

In figure 96, the a. v. c. circuit is shown in heavy lines. The rectified signal voltage necessary for the operation of an a. v. c. circuit is taken from the negative end of the potentiometer *R,* and returned to the first two stages of the receiver. Note that only the first and second r. f. amplifiers are supplied wih an a. v. c. voltage in this receiver. A switch is provided for short-circuiting the

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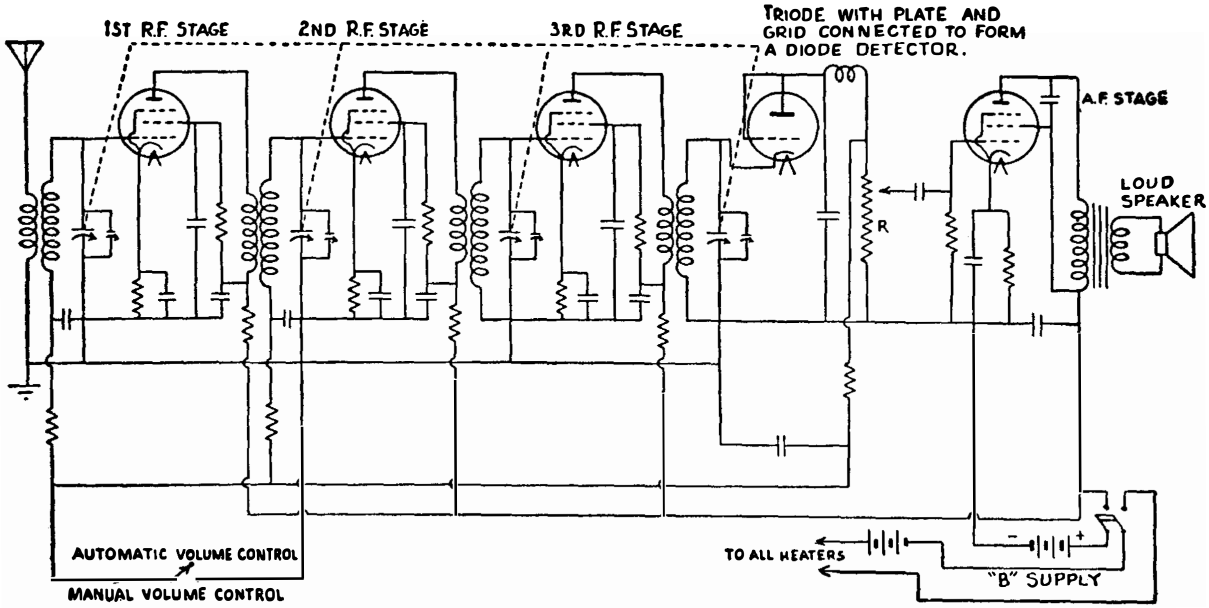

Figure 93.—Elements at high r. f. potential denoted by heavy lines.

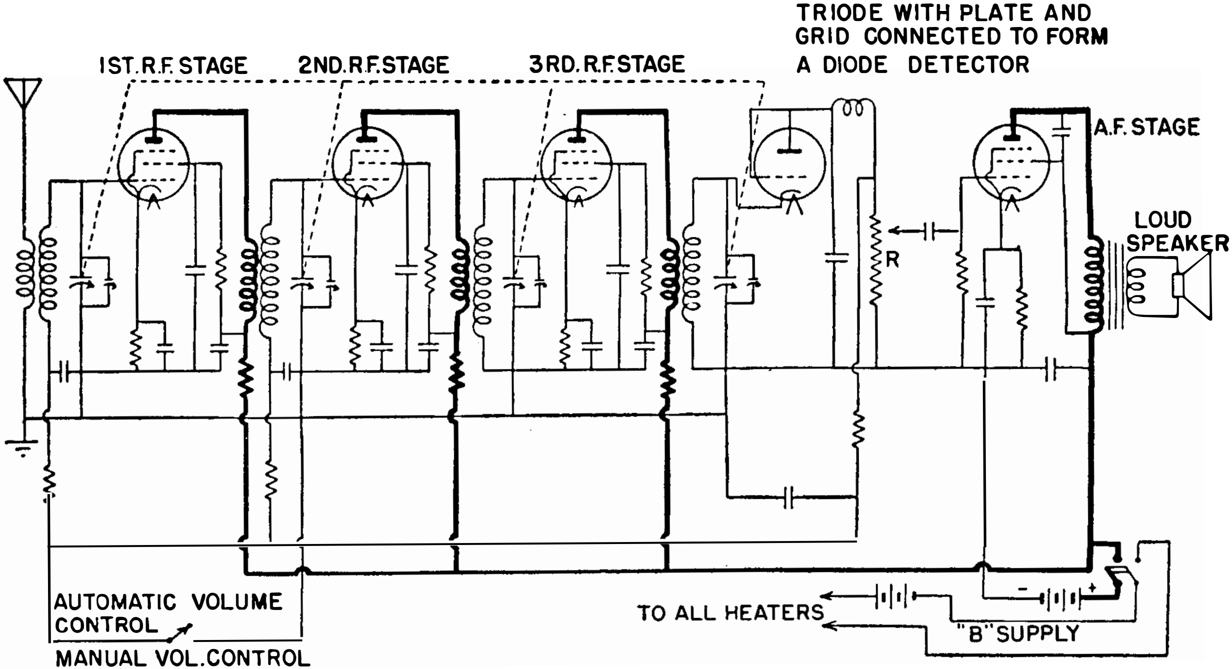

Figure 94.—Direct-current plate supply shown in heavy lines.

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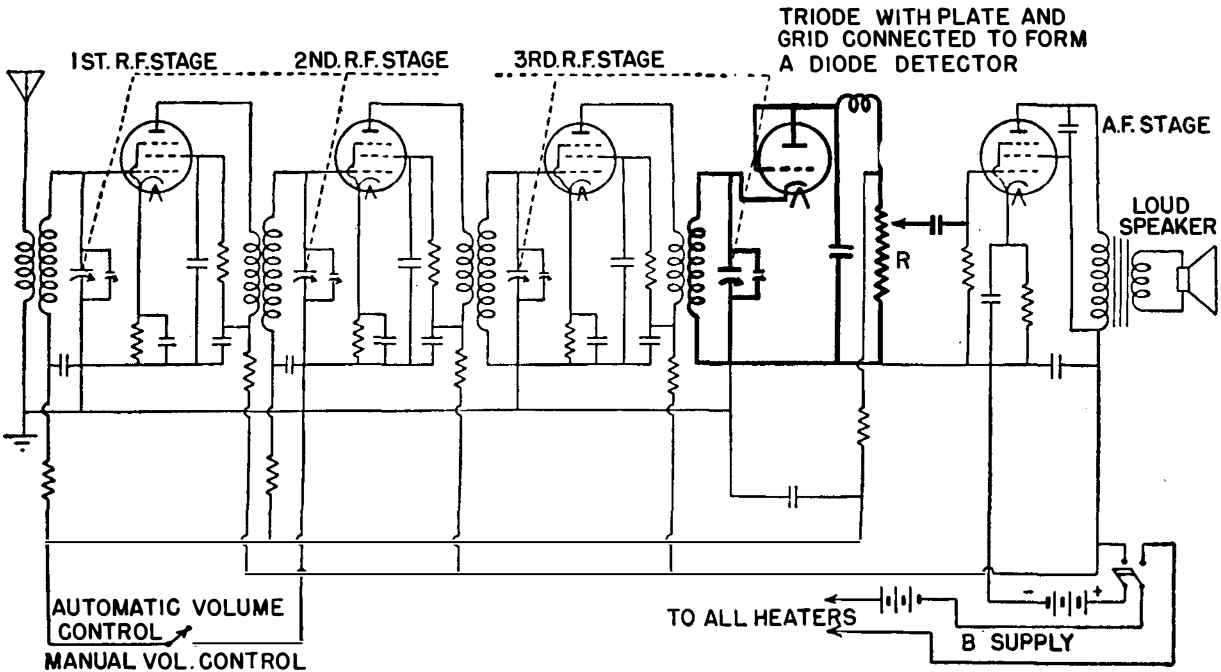

Figure 95.—Detector circuit shown in heavy lines.

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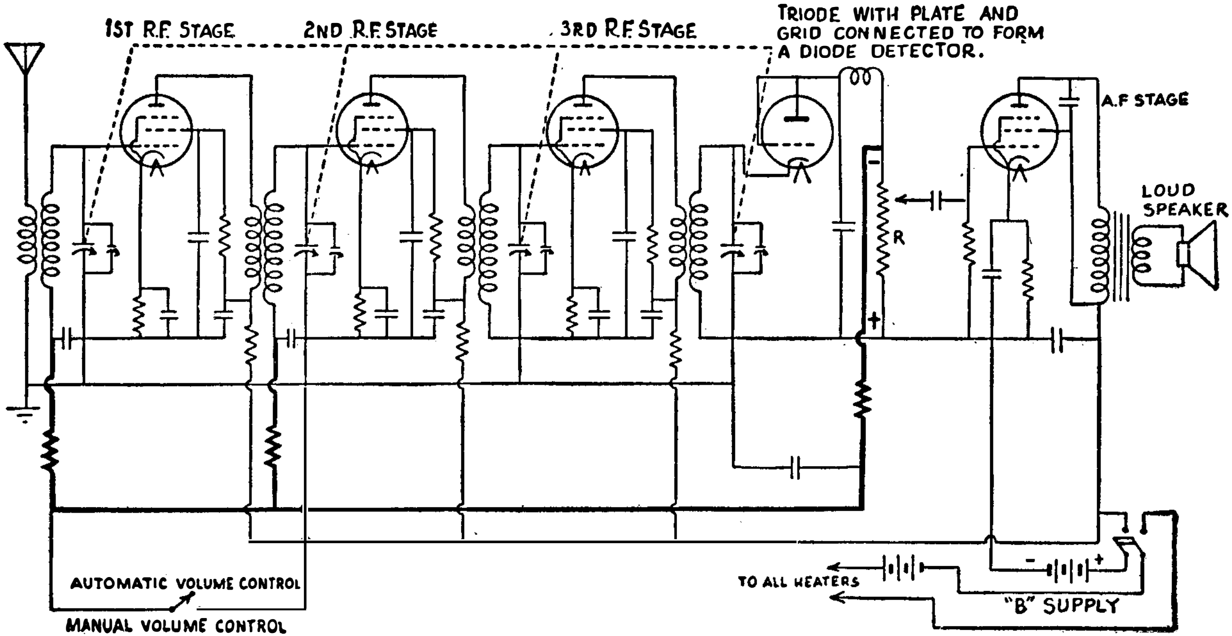


Figure 96.—Automatic volume control circuit shown in heavy lines.

a. v. c. when it is not desired. If this is done, the potentiometer *R* is then used as a manual control of volume without affecting the normal operation of the t. r. f. receiver.

CAPABILITIES OF T. R. F. RECEIVER

Although the t. r. f. receiver will give you satisfactory results when covering a single low- or medium-frequency band, it has several disadvantages which make it impractical for use in high-frequency or multiband receivers. The chief disadvantage of the t. r. f. receiver is that its selectivity (ability to separate signals) does not remain constant over its tuning range. As the set is tuned from the low-frequency end of its tuning range toward the higher frequencies, its selectivity decreases. At high frequencies, which are widely used for Navy communications, this lack of selectivity becomes extremely troublesome. Also, the amplification, or gain, of the t. r. f. receiver is not constant with frequency. It is very difficult to design r. f. amplifiers that will provide enough amplification for communication requirements at extremely high frequencies. The superheterodyne receiver has been developed to overcome these disadvantages.

SENSITIVITY MEASUREMENTS

Receiver sensitivity, you recall, is the MINIMUM amount of input signal which is required in order to produce a desired output. The term "desired output" is technically correct, but for communications receivers which work into headphones as a load, you can accept as an arbitrary standard for desired output, 6 milliwatts of power expended in the load.

The required equipment includes a standard signal generator. The signal generator should have a frequency range adequate to cover all communication frequencies, good frequency calibration, and stability. Above all, it must have an accurately calibrated output.

A suitable dummy antenna is necessary in order to "fool" the receiver into thinking it is connected to an antenna rather than to a signal generator. The reactance reflected into the receiver input circuit by an actual antenna makes this necessary.

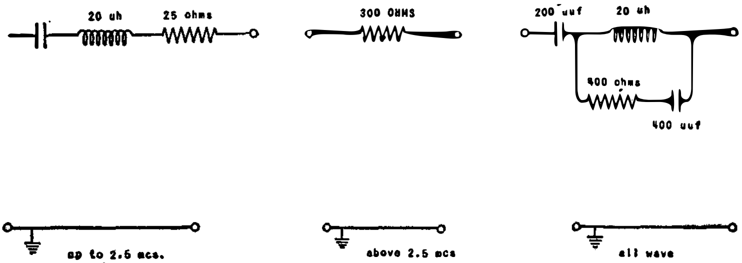


Figure 97.—Schematic of dummy antennas.

In order to reflect the same amount of reactance, either one of the following arrangements may be used within its frequency limits: (1) Any rectifier type a. c. voltmeter will do as an output indicator. It should have a sensitivity of at least 1,000 ohms per volt. The Weston model 695 power level indicator is a very good instrument for this purpose. When working with the Weston 695, for convenience use the db. scales. However, do not attempt to use the db. meter without fully understanding its use. (2) Since most meters are calibrated across a resistance load (DUMMY LOAD), it will be necessary to provide this resistance in place of the telephones. For instance, most receivers are designed to work into a 600-ohm load. In this case a 600-ohm resistor must be used as a load. For listening-in purposes a pair of high impedance phones may be shunted across the load without any appreciable error in the readings; always be certain that the receiver is working into the proper load when taking measurements.

NOTE: Most standard Navy type receivers are equipped with an output meter on the front panel. This output meter is calibrated across a 600-ohm load and may be used as the output indicator. A set of 600-ohm phones may be used as a load in lieu of a 600-ohm resistor.

The proper instruction book is necessary in order that exact instructions for a particular model of receiver may be carried out. This is especially true for the proper settings of the controls and auxiliary circuits which would affect the measurements and the table of normal readings.

Figure 98.—Hookup for receiver sensitivity measurements.

Following is the procedure for making a sensitivity measurement:

1. Connect the equipment as shown in figure 98.

2. Turn on the equipment and allow it approximately 10 minutes to warm up.

3. Determine from the instruction book whether the measurement is to be taken with a c. w. or m. c. w. signal and follow the manufacturer's instructions concerning receiver control settings.

4. Set the signal to one of the measuring frequencies. Normally when testing a superheterodyne receiver three measurements are taken for each frequency band.

5. Tune the receiver accurately to this signal regardless of dial calibration. Keep the signal input low to prevent overloading the receiver. For this tuning operation it is best to use phones to make the rough tuning adjustment and to put the output meter in the circuit only when it is certain that it will not be over-loaded. Adjust all

controls accurately for maximum output. Do not forget to adjust the antenna compensator. If a c. w. measurement is being taken, tune to both sides of zero beat and use the side giving the greatest output. To make sure the receiver is not tuned to a signal other than that of the signal generator turn off the plate switch of the signal generator and check whether the signal disappears. THE RECEIVER MUST BE ACCURATELY TUNED TO THE SIGNAL.

6. After the receiver is properly tuned, you come to another important part of the measurement. You must now establish the proper setting of the gain control. This control is exactly what the name implies, and will therefore change the receiver amplification. It is evident that for ten different settings of the gain control you would obtain ten different sensitivity readings. Consequently, in order to have some fixed reference point for setting the receiver gain, the noise level is used as a standard. The next step, then, is to set up the proper value of noise voltage in the output. THIS VALUE IS OBTAINED FROM THE INSTRUCTION BOOK. The noise level is adjusted to this value by means of the receiver gain control. ALWAYS REMOVE THE SIGNAL WHEN SETTING THE GAIN CONTROL TO THE NOISE LEVEL. This is done by turning the signal generator plate switch to OFF. Never disconnect the signal generator to turn the main switch off.

7. Turn the signal generator attenuator controls to zero; when the plate switch is turned on it will not damage the output meter.

8. Starting from zero, gradually increase the output from the signal generator until standard output is obtained on the output meter. The reading at this point on the signal generator attenuator controls, read in microvolts, is the sensitivity of the receiver for that particular frequency.

The procedure outlined above is repeated for each frequency measured. Remember to tune the receiver accurately, adjusting for the proper noise level each time. Set the signal generator output to zero before turning the plate switch to ON. Adjust the attenuators accurately for standard output. If it is impossible to obtain standard noise level, SET THE GAIN CONTROL TO MAXIMUM.

If low sensitivity is present on all bands this will generally indicate poor tubes or some defect which is common to all bands. A low sensitivity on only one or two bands will indicate that the trouble is in that part of the circuit. It may be the result of defective coils, capacitors, etc., associated with that particular part of the circuit.

Good sensitivity at one end of the band and poor sensitivity at the other end usually indicates poor tracking of the heterodyne oscillator and means a circuit alinement job.

SUMMARY

Sensitivity is one of the most important characteristics of any communication receiver. It is the quality which enables the receiver to do its work. Without sensitivity the receiver is useless.

Routine measurement of receiver sensitivity is important because it gives a constant check on the operating condition of the receiver. Periodic measurements are required by the *Bureau of Ships Manual.* These measurements should be made when required and a record kept of the result. A measurement should be taken at the high end, middle, and low end of every band. In this manner it is possible in many cases to catch a receiver which is going bad slowly and to repair it before the trouble results in a complete failure, which may come at some inconvenient time.

Read the manufacturer's instructions carefully, for one small mistake will make your measurement worthless. Remember, receiver control settings and normal sensitivity readings will vary with different types of receivers. Always compare your sensitivity readings with those furnished by the instruction book.

TROUBLE-SHOOTING

Progressive sensitivity measurements are required for effective trouble shooting. They give you a complete check of the signal channel of a receiver from the phones to the antenna terminal in a consecutive and uninterrupted series.

To fully understand this method of trouble-shooting you must realize that, when applying a signal to consecutive stages of a receiver, you are utilizing only that portion of the receiver between the stage to which you apply the signal and the output. Also keep in mind that each stage, except the oscillator, is designed to amplify and to pass on to the succeeding stage the particular frequency (r. f., i. f., or a. f.) for which it was designed. With this in mind, and with a common type of superheterodyne as an example, let us consider the output stage of the receiver.

The output stage is designed to amplify and pass on to the reproducer (speaker or phones) an a. f. signal applied to its grid, the amount of amplification having been carefully decided by its design engineer.

Assuming the amplification to be 10, you could check the stage by applying an a. f. signal to its grid and measuring its output voltage. If the output voltage is found to be the input voltage times 10, then normal operation of the output stage is indicated. However, in most standard Navy receivers you already have a meter to measure the output of the final stage, namely, the output meter. Here is how you use this meter as a measure of the gain of each stage.

First, let's return to our consideration of the output stage of the receiver. If 2 volts applied to its grid will give us 20 volts in its output, it is logical to assume that there is some value of applied voltage which will give us 1.9 volts or standard output in the output meter. If this value of applied voltage is known you can check the output stage by applying this input to its grid and noting the reading of the output meter.

By the same logic there is some value of input to every stage of the receiver which (with the receiver operating normally) should give standard output.

Notice as you go back through the receiver toward the antenna terminal that the signal input necessary for standard output becomes less and less because you are using the gain of the stages already tested to amplify the signal finally applied to the output meter.

Definite values of signal input at various stages (to produce standard output) have been determined by the manufacturer and may be found in the instruction book of most Navy receivers.

PROCEDURE

Although normal values of signal input are not usually available for the audio system, these stages may be checked individually by estimating the stage gain from circuit values and tube characteristics. This is seldom necessary however because an over-all test of the audio system will indicate if any trouble exists in that portion of the receiver. Other standard means of checking may be used to locate the exact circuit in which the trouble may be.

The procedure for testing the intermediate frequencies is similar to that on the a. f. stages, with the amount of signal input usually obtainable from the table in the instruction book. Any stage which does not indicate standard output after the succeeding stages have been found normal should be checked for trouble, and repaired.

The b. f. o. (beat frequency oscillator) may be tested after checking the i. f. stages by using a c.w signal output from the signal generator. If a normal signal can be obtained using a modulated signal, but none when using c. w., it is a good indication that the b. f. o. is not functioning.

Having checked the i. f., you can proceed with the remaining stages—the mixer, heterodyne, oscillator and the r. f. stages. The mixer normally contains three frequencies in which you are interested, r. f., oscillator, and i. f. By applying the designated amount of i. f. you can check the operation of the mixer at the i. f. The next step is to apply an r. f. signal to the mixer grid with the tuning dial of the receiver set to this frequency. (This places the oscillator at the correct setting to give proper i. f.) If output is not obtained, slowly rotate the tuning dial to change the oscillator frequency. If you still get no output, it is evident that no oscillator frequency is mixing with the radio frequency, indicating the trouble must be associated with the heterodyne oscillator.

The above deduction is easy to understand. You know that if you get the proper intermediate frequency in the mixer, you will get standard output, because you have just applied this frequency to the mixer grid from the signal generator. Now, if you apply a radio frequency signal, it should beat with the oscillator frequency to give you the intermediate frequency and output. If no output is obtained, you know that the oscillator frequency is not present. As a special precaution, be sure the heterodyne oscillator is tuned to the proper frequency by adjusting the main tuning dial.

If the heterodyne oscillator is found to be normal, the progressive sensitivity measurements are continued through the r. f. stages with the final check being made at the antenna terminal.

Experience has shown that a man is apt to make numerons mistakes regarding frequency input, proper amount of input and adjustment of the front panel controls. This may send you on a "wild goose chase" for troubles that do not exist. For this reason too much emphasis cannot be placed on care, common sense and the careful reading of and compliance with the instruction book. Many instruction books are provided with progressive sensitivity measurements. In case your receiver is not accompanied by an instruction book containing these measurements, you may provide your own by taking measurements when your receiver is in good working condition.

RELATIVE SENSITIVITY MEASUREMENTS

Relative sensitivity measurements is a method of trouble-shooting in which you test each individual stage for the amplification and passage of its designed frequency. This method, while not as positive as progressive sensitivity measurements, is very useful because the equipment necessary is usually at hand. No progressive sensitivity measurements are then necessary, and any signal generator with the necessary frequency coverage may be used.

Relative measurements are quite similar to progressive sensitivity measurements except that the input is not critical, and you use an audible indication to measure the gain of each stage.

NOTE: The output meter must be cut out of the circuit, due to the possibility of overload and damage to the meter.

The starting point remains the same—that is, an a. f. signal on the grid of the output stage. An audible output will then show the output stage to be passing the signal. Now reduce the input until the output is at a very low level. If you apply this same signal strength to the grid of the preceding stage, the audible output should increase. This shows that the second stage (from the phones) is amplifying and passing the signal.

This procedure is repeated for every stage in the receiver, but remember—

1. To change frequencies at the i. f. and r. f. stages.

2. That some types of second detector are not designed for gain but should pass the signal with slight attenuation.

3. That some stages of audio have a considerable amount of degeneration and as a result the gain is quite small.

Check the oscillator according to the procedure described before. That is, check the mixer with the intermediate frequency and the oscillator with an r. f. signal on the same (the mixer) grid.

PRECAUTIONS

After checking each stage the signal input MUST be turned down to give a low output level, otherwise the receiver may overload when the signal is placed on the preceding stage. This would indicate that a stage is attenuating the signal when it is actually amplifying the signal and working normally.

A blocking capacitor must ALWAYS be placed between the signal generator and the receiver to protect the attenuator network in the signal generator. Before checking for trouble in the receiver itself the power supply should be eliminated as a source of trouble. Remember that a very large percentage of receiver trouble is due to defective tubes.

ALINEMENT OF TUNED CIRCUITS

The adjustment of the tuned circuits of a receiver should not be changed before you have satisfied yourself that poor performance is due to misalinement. A measurement of the sensitivity of a receiver with good tubes is an excellent test to determine whether the receiver in question is in need of alinement.

There are numerous reasons why receiver alinement may be necessary. Changing tubes may throw a receiver out of alinement because of lack of uniformity in the interelectrode capacities of the tubes. This is especially noticed in receivers designed for high frequency reception. Movement of radio or intermediate frequency wiring may necessitate realinement, because changes in the position of the wiring influence the tuning of the receiver circuits. The aging of vital parts associated with the tuned circuits is another important factor which makes alinement necessary.

A good signal generator and an output indicator are essential. Where visual alinement is desired an oscilloscope must be used. In addition, necessary tools such as insulated screw drivers and wrenches must be on hand as well as manufacturers' data, instruction books, circuit diagrams, etc. While it is true that in the great majority of cases, alinement follows along the same general lines, some receivers require definite departures from the established routine; hence, the necessity for using specific instructions from instruction books furnished with the equipment.

OUTPUT INDICATOR CONNECTIONS

The output indicator arrangement in general use is the low range a. c. voltmeter which is connected across the output terminals of the receiver. Another method consists of connecting an a. c. voltmeter across the primary of the output transformer. If the output stage consists of two tubes in push-pull, the output indicator may be connected from the plate of one tube to ground, or from plate to plate. In all cases, you should use a blocking condenser in series with the meter to protect it against any high voltage direct current. Where a triode detector is used, a d. c. voltmeter connected across the detector bias resistor can be used. A microammeter or low range milliammeter may be placed in the plate circuit of the detector. Due to their limited use however, the above-mentioned systems, with the exception of the a. c. voltmeter connected across the output terminal, are not always practicable.

A. V. C. ADJUSTMENT DURING ALINEMENT

Receivers with a. v. c. require that special attention be given to the signal input to the receiver during alinement. When possible leave the a. v. c. in the OFF position. This is necessary when you operate below the point at which the a. v. c. circuit levels off the response.

TRIMMER ADJUSTMENTS

To avoid hand capacity effects, the receiver should be grounded and all tube shields in place. The screw drivers and socket tools should contain no metal. A trimmer should never be left loose in its minimum capacity position. If necessary, bend the end plate so that the nut rests firmly against the plate. All adjustments should be repeated since there is a certain amount of reaction between various stages. Trimmers should never be forced because there is always the possibility of stripping the threads.

ALINEMENT AND NEUTRALIZATION OF T. R. F. RECEIVERS

Alinement

Your first step is to connect the output from a standard signal generator to the receiver antenna-ground terminals. This connection should be made through the proper dummy antenna and is usually specified in the manufacturer's instruction pamphlets. Tune the signal generator to the frequency specified as the high alinement frequency. If no frequency is specified, any frequency near the high end of the band will be satisfactory. Set the receiver tuning dial to the correct calibration for the particular frequency used. With the receiver volume control advanced until the noise level is just appreciable, adjust the output from the signal generator so that the output indicator reads about half-scale. If the receiver dial calibration is so far off that the signal does not come through, a slight adjustment of the detector trimmer will usually bring the signal in. Adjust trimmers, working from the detector towards the antenna, and adjust for maximum output. Always maintain the output within the limits of the output indicator by turning back the attenuator on the signal generator or reducing the volume control. Check the alinement at other frequencies throughout the band. In receivers, using slotted condenser plates, alinements are effected by bending the segment away from or toward the next plate of the condenser.

Before alining, all receiver controls such as selectivity, sensitivity, automatic volume control, etc., should be set according to the manufacturer's specifications. Practically all alinement, except c. w. oscillators, is carried out with the signal output from the signal generator modulated. There is this exception: in low frequency receivers pure c. w. should be used to exclude side band cutting. Correct calibration of the signal generator is essential. Before attempting alinement, it is good practice to allow the receiver and signal generator to reach their normal operating temperature. About 15 minutes is sufficient.

Neutralization

When a triode is used as a radio frequency amplifier, the capacity between the grid and plate of the tube tends to cause an energy feedback from the plate circuit to the grid circuit, resulting in serious instability and oscillation. This feedback can be neutralized by feeding back a portion of the voltage in the output circuit to the grid circuit in such a way as to cancel out the voltage induced on the grid through the grid-plate capacity. Each stage is individually neutralized by its own neutralizing condenser. This is most easily effected by the use of a dummy tube, that is, a tube similar in every way to the tubes in the radio frequency amplifier, but with one heater or filament prong removed. The associated neutralizing condenser is always adjusted for minimum output. During this procedure the signal generator is connected as for alinement and the receiver neutralized as some frequency lower than that already neutralized. A check of receiver alinement is always necessary upon completion of neutralization.

You must remember that the preceding paragraphs are only an outline of actual alinement and neutralizing instructions. Since different type receivers employ different methods of alinement and neutralizing, special instructions are always placed in the instruction book for each particular receiver.

Preventive Maintenance

It's a good idea to test each idle receiver daily to see if the gear is in working order. In this way you will be sure it is always operating properly, thus avoiding the unpleasant experience of finding it inoperative when it is most needed. It is advisable to check the speed of rotation of receiver power supply motor generators at least weekly. This is done to see if the motor speed is up to standard r.p.m. If it isn't, it will be easier for you to determine the cause and to fix it before the generator fails. Of course, when you are being supplied a. c. current from the ship's main generators, the need for this check is eliminated.

At least once each month, install a complete set of tested vacuum tubes in all receivers which are used extensively. Be sure to include your direction finder in this installation. Receivers not in constant use should be checked periodically for faulty tubes. When you remove tubes from a set, give them an immediate test so that the satisfactory ones may be retained for further use.

Check radio direction finder calibration curves on at least five points and on at least three frequencies, using transmitting stations or bearings which can be determined accurately by visual or navigational means. Vary check points and frequencies as may be practicable in subsequent monthly tests.

Measure receiver noise level in each band according to current instructions issued by the Bureau of Ships.

All sliding mechanical contacts should be lubricated lightly with nonfluid mineral oil or vaseline. Be sure all excess lubricant is wiped off, because dust or lint will collect on the parts and leave them in worse operating condition.

For quarterly inspections and tests, make sensitivity measurements of all receivers in accordance with current instructions, and record the results of these tests prior to and after any corrective action has been taken.

Check the operation of the receiver volume limiter and audio tuning controls. These devices do not require any adjustment or trimming. The vulnerable points are the controlling toggle switches, potentiometers, and vacuum tubes. Most trouble will be experienced with the toggle switches because they are operated so seldom and carry and break such small voltages and currents that the small amount of oxide that occurs on their contacts will render them inoperative. Periodic operation, for 10 or 20 minutes, will usually keep these switches in good condition. Clean switches when their contacts are oxidized. Potentiometers usually open circuit due to wear and when this occurs must be replaced. Limited vaccum tubes are used as rectifiers only, and are critical only to emission and low gas content.

Check the calibration of each receiver for operating frequency in actual use or for which the receiver is standing by. The calibration should be checked by an accurate frequency meter in the manner prescribed by the instruction books for these instruments. As most receivers have a slight frequency drift with time and temperature changes, they should be turned ON for at least one-half hour before checking.

Measure the receiver noise level at operating frequency in actual use (or, for which the receiver is standing by) and record the results of tests prior to and after corrective action, if any, has been taken.

Check the inventory of receiving type vacuum tubes and requisition necessary tubes to complete your allowance.

During semiannual tests and inspections, check the alinement of all receivers in accordance with current instructions. Check their condition prior to and after alinement, making suitable entries in the log.

Personnel responsible for making these inspections and tests arrange, where practicable, for substitute equipment to be used during inspections and tests. Otherwise, proper authority must be obtained for temporarily decommissioning equipment where substitute equipment is not available.

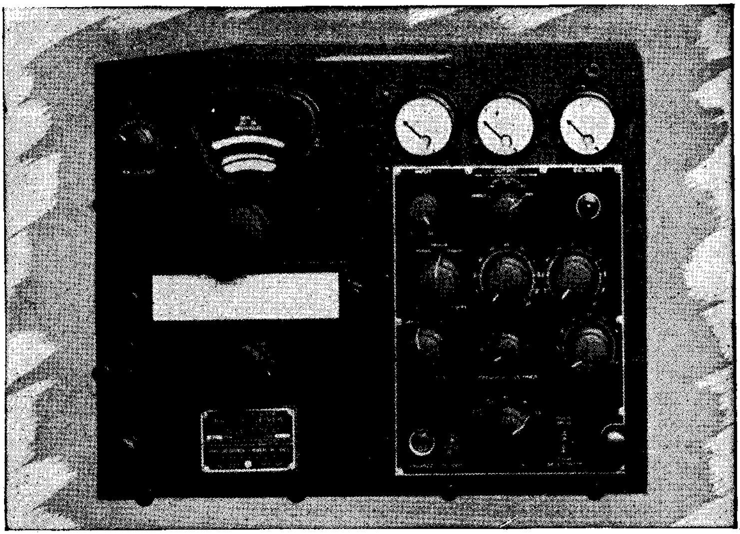
When inspections and tests cannot be made, for any reason, a complete statement of the circumstances should be entered in the appropriate log and the responsible officer notified. In this event, the test shall be made at the first opportunity.

When these conditions are carried out, you will have less maintenance trouble and the life of your equipment will be extended considerably.

QUIZ

1. How are resistors generally classified?
2. What is the purpose of tuned r. f. amplifier stages in t. r. f. receivers?
3. What is the chief disadvantage of the t. r. f. receiver?
4. What step must be taken after a receiver has been neutralized?
5. Why should trimmers never be forced?

6. What test can be used to determine whether a receiver is in need of alinement?
7. What are the two most widely used detector circuits?
8. How can you increase the amount of band spread so that it tunes only a small portion of the coil?
9. What does a voltage divider do?
10. How is coupling between two circuits prevented in a receiver?



CHAPTER 6

THE SUPERHETERODYNE RECEIVER

A NEW FREQUENCY

You shouldn't have any trouble understanding the essential difference between the t. r. f. receiver and the superheterodyne receiver. In the first type the r. f. signal is amplified at the frequency of the incoming signal. In the superheterodyne, on the other hand, the signal is amplified at a new, lower frequency, called the INTERMEDIATE frequency.

The shortcomings of the t. r. f. receiver are largely overcome in the "superhet" by beating the received signal with a different frequency to produce a lower intermediate frequency. Though much lower than the original this new frequency retains all the modulation characteristics of the old signal. By amplifying this lower frequency, it is possible to use circuits which are more selective and capable of greater amplification than those used in t. r. f. receivers. The block diagram of a typical superheterodyne receiver in figure 99 shows you how the signal changes as it goes through the different

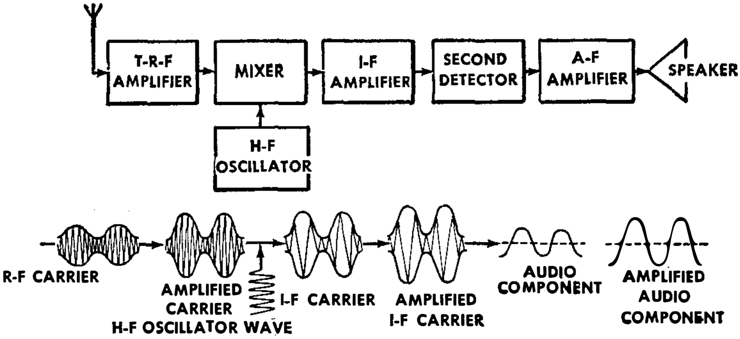


Figure 99.—Superheterodyne receiver, showing signal passing through receiver.

stages. The receiver r. f. signal is first passed through an r. f. amplifier. A locally generated, unmodulated r. f. signal is then mixed with the carrier frequency in the mixer stage. This produces an intermediate frequency signal which retains all the modulation characteristics of the original signal, but is much lower in frequency. This intermediate frequency is amplified in one or more stages, called intermediate frequency amplifiers, and is then fed into the second detector, where it is detected or demodulated. The detected signal is amplified in the a. f. amplifier and then fed to a headset or loud-speaker.

The conversion of the original r. f. signal to the intermediate frequency is an important function of the superheterodyne receiver, By using a vacuum tube as a detector, it is possible to change the frequency of a radio signal to another frequency, and yet retain everything that existed in the original signal. This process is known as frequency conversion. The tube is called a mixer or converter, and sometimes a first detector. If a 1,000-kilocycle signal and 1,465-kilocycle signal are fed into a mixer, various frequencies are obtained in the output. One of the most prominent of these is the beat frequency, which is the difference between the two, or 465 kilocycles. This is the intermediate frequency. In the superheterodyne receiver these two signals come from different sources, one of them being the received signal. The other comes from a special stage used in all superheterodynes, known as the local, or heterodyne oscillator. Unlike the received signal, the signal from the heterodyne oscillator is unmodulated. In the superheterodyne receiver the intermediate frequency is set at a definite value. The frequency of the local oscillator must be tuned simultaneously so that its frequency is always separated from that of the received signal by the same amount. For example: if the intermediate frequency is 465 kilocycles—a commonly used frequency—and the range of the receiver is from 500 to 25,000 kilocycles, the oscillator would have to operate over a range of either 35 to 24,535 kilocycles or 965 to 25,465 kilocycles. Whether the oscillator frequencies are higher or lower than the signal, the difference is still 465 kilocycles. The higher range is generally used, except when receiving signals on rather high frequencies. The i. f. amplifier stages are permanently tuned to 465 kilocycles.

Frequency Conversion

The combined circuits of the oscillator stage and mixer stage form the frequency converter of the superheterodyne receiver. There are a large number of possible combinations of tubes and circuits which may be used for frequency conversion. Triodes, pentodes, and multi-element tubes are used in various circuits, and several methods are used to mix the oscillator-output frequency with the incoming-signal frequency in the mixer stage. The oscillator output may be injected into the control grid, cathode, screen grid or suppressor grid of the mixer tube; or the coupling may be a special grid built into the tube for that purpose. Multielement converter tubes have been so designed that the functions of oscillating and mixing can be combined in one tube. The pentagrid converter tube is an example of this widely used type.

When the frequency converter uses a separate, single tube as a local oscillator, the basic circuit is similar to the diagram shown in figure 100. A pentagrid (five-grid) mixer tube combines the frequency from the oscillator (usually a triode) with the incoming r. f. carrier.

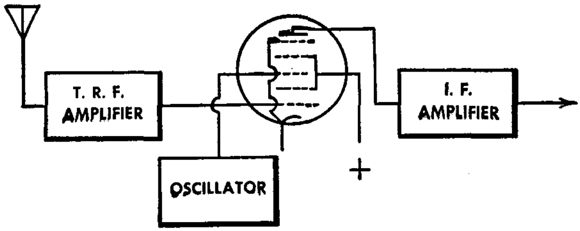


Figure 100.—Pentagrid mixer.

A typical frequency-converter circuit using a triode oscillator and a triode mixer is shown in figure 100. The oscillator output is fed or injected into the grid of the mixer through a coupling capacitor, a process known as grid injection. The coil and tuning capacitor in the mixer-grid circuit are tuned to the frequency of the incoming r. f. signal. The oscillator-grid circuit is tuned to a frequency lower or higher than the signal frequency by an amount equal to the intermediate frequency. The i. f. transformer in the plate circuit of the mixer stage is tuned to the intermediate frequency. The oscillator uses the same circuit as the regenerative detector studied previously. The feedback is of such a value that the circuit is oscillating at a frequency determined by the values of L and C. The capacitors C and $C1$ are ganged so that, as the frequency of the signal being received is changed, the oscillator frequency will also be changed by the same amount.

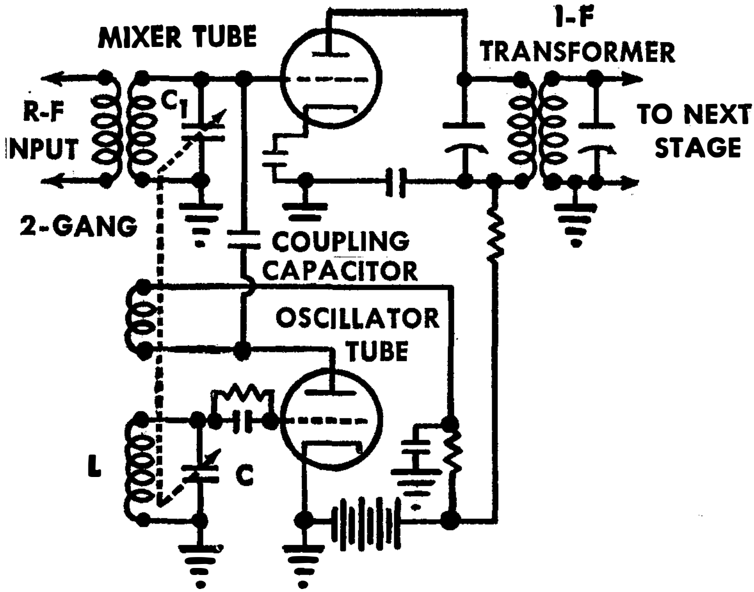


Figure 101.—Frequency converter circuit using triode oscillator and triode mixer.

Two other ways of coupling the mixer and local oscillator are shown in figure 102, where a pentagrid mixer and triode oscillator are used. Figure 102(1) shows the local oscillator coupled to the mixer tube by coil $L3$ in the cathode circuit of the mixer tube. The r. f. voltage induced in coil $L3$ causes the plate current of the mixer tube to fluctuate at this frequency. The incoming signal induced in coil $L2$ in the grid circuit of the mixer also affects the plate current. These two frequencies are mixed together and the beat between them, which is the i. f. frequency, will be produced in the tuned plate circuit. Interaction between the oscillator and mixer is reduced somewhat by coupling the oscillator voltage to the cathode. Figure

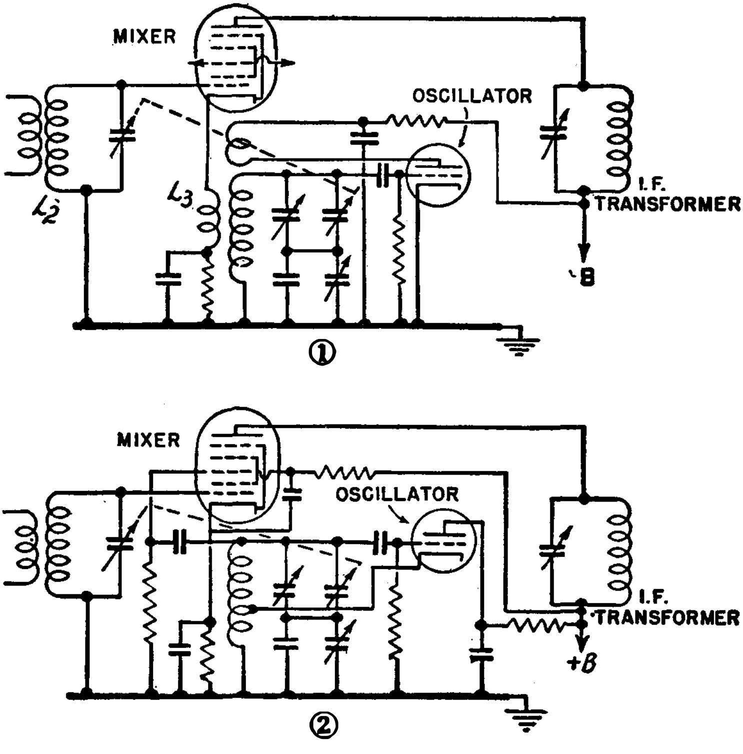


Figure 102.—Local oscillator-to-mixer coupling methods.

102(2) shows a second method of frequency-conversion coupling between a pentagrid mixer having two independent control grids and a separate local-oscillator tube. In addition to a heater and cathode, the tube has five concentric grids and a plate. Grid 1, nearest the cathode, and grid 3 are the control grids of the tube, while grids 2 and 4 are screen grids. Grid 5 is a suppressor grid. The local oscillator is coupled to the signal grid. The voltages applied to these grids affect the plate current, thus producing a beat note or intermediate frequency in the plate circuit of the tube. This tube provides superior performance in the high frequency bands because of the excellent shielding between the oscillator and signal grids.

Another type of frequency conversion employs a single tube having the oscillator and frequency mixer combined in the same envelope. This type tube also has five grids, and is called a pentagrid converter. The basic circuit for the pentagrid converter is shown in figure 103. Compare it with the diagram in figure 100. The pentagrid converter depends on the electron stream from the cathode for coupling. The plate current is modulated by variations in the cathode emission. The performance of a pentagrid converter is such that only one tube is necessary for converting the frequency of the desired signal from its original value to an intermediate frequency. Grids 1 and 2, and the cathode are connected to a conventional oscillator circuit and act as a triode oscillator. Grid 1 is used as the grid of the oscillator, and grid 2 is used as the plate. In this circuit, you can consider the two grids and the cathode as a composite cathode, which supplies an electron stream that varies at the oscillator frequency. The signal voltage is applied to grid 4, which further controls the electron stream so that the plate current variations are a combination of the oscillator and the incoming-signal frequencies. The plate circuit of the pentagrid converter is tuned to the desired intermediate frequency. Grids 3 and 5 are connected within the tube to form a screen grid which accelerates the electron stream and shields grid 4 from the electrodes.

A typical pentagrid-converter circuit is shown in figure 104. The incoming r. f. signal is fed from $L1$ into the tuned grid circuit of $L2$ and $C1$. It is then applied to the control grid of the tetrode section of the tube at grid 4. In the oscillator section of the tube, the r. f. energy is fed back from the plate circuit inductance *L*4 to the tuned grid circuit consisting of *L*3, *C*2, and *C*4. *C*2 is the main tuning capacitor. Bias for the tetrode section

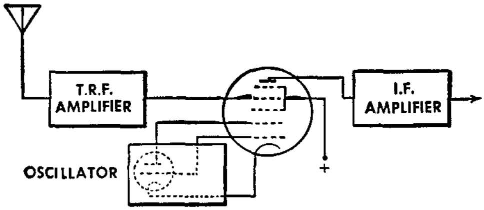


Figure 103.—Pentagrid converter.

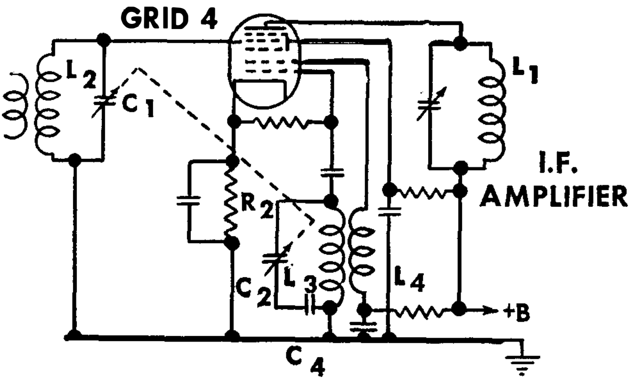


Figure 104.—Coupling of oscillator to mixer by means of modulating electron stream from cathode of mixer tube.

of the tube is secured by the flow of plate current through the cathode resistor *R*2. The incoming signal, and the oscillator voltages are heterodyned in the electron stream flowing from cathode to plate. The output voltage is a beat frequency equal to the difference between the incoming signal and the oscillator frequencies.

The capacitor $C4$, placed in series with the tuning capacitor $C2$, is called a padding capacitor. This padding capacitor is necessary because the frequency of the oscillator tuned circuit is higher than that of the r. f. circuit. It is necessary to have a low value of inductance and capacitance in the oscillator circuit to obtain a higher frequency. In some superheterodyne sets, this is accomplished by having a smaller capacitor and coil in the oscillating circuit. In others, such as you will find in figure 103, it is more convenient to use the same size capacitors in both circuits and reduce the value of the oscillator capacitor by placing a fixed or variable capacitor in series with it. A small trimmer capacitor may also be placed across the oscillator tuning capacitor to take care of any slight frequency deviations.

I. F. Amplifiers

The intermediate frequency amplifier is a high-gain circuit fixed-tuned to the frequency difference between the local oscillator and the incoming r. f. signal. Pentode tubes are generally used in these amplifiers, which may consist of one, two, or three stages. Each stage is adjusted to the selected intermediate frequency. Since all incoming signals are converted to the same frequency, this amplifier operates at only one frequency. The tuned circuits, therefore, may be permanently adjusted for maximum amplification and desired selectivity. Practically all of the voltage amplification and selectivity of the superheterodyne is developed in the i. f. stages.

The i. f. transformers used with i. f. amplifiers are tuned by adjustable, or trimmer, capacitors to the desired frequency. Both mica and air-trimmer capacitors are used. Generally, the i. f. transformers are double tuned, that is, both primary and secondary coils are tuned to the proper frequency. For special applications, single-tuned i. f. transformers are used, in which case the secondary winding alone is tuned. Intermediate frequency transformers are made with both air and powdered-iron cores. Some iron-core i. f. transformers have fixed mica tuning capacitors, and the tuning is done by varying the inductance. Iron cores are moved in or out of the coil by an adjusting setscrew. This is known as permeability

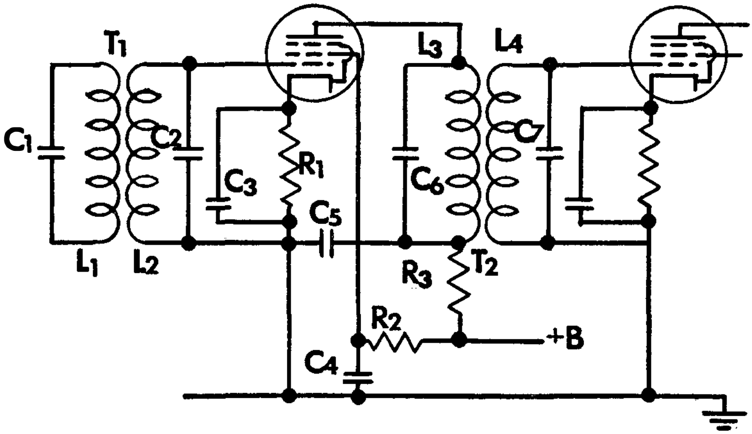


Figure 105.—Circuit diagram of a single-stage i. f. amplifier using pentode tube.

tuning. The i. f. transformers and capacitors are mounted in small fixed metal cans which serve as shields. When adjustable capacitors and fixed inductors are used, the capacitors are small compared with the large ganged tuning capacitors used in r. f. stages. Small adjusting shafts protrude from the top of these capacitors and can be reached through a small hole in the can by using a hexagonal wrench or screw driver. Thus, the capacitor can be adjusted without removing the assembly from the shield.

The diagram of a single-stage i. f. amplifier using a pentode tube is shown in figure 105. Transformer *T*1 is the input i. f. transformer. The primary of the transformer, *L*1–*C*1, is in the plate circuit of the mixer and is tuned to the selected intermediate frequency. The secondary circuit, $L2$–$C2$, which is inductively coupled to the primary, is tuned to this same frequency and serves as the input circuit to the grid of the tube. Resistor $R1$ in the cathode circuit provides the necessary bias voltage, while capacitor $C3$ bypasses r. f. currents around this resistor. Resistor $R2$ and capacitor $C4$ are the screen voltage-limiting resistor and the screen bypass capacitor, respectively. Resistor $R3$ and capacitor $C5$ serve as a decoupling network to prevent signal currents from flowing back through the circuit and causing interaction between stages. Capacitor $C5$ furnishes a low-impedance path to the cathode or ground for the signal currents, while resistor $R3$ prevents any signal current from flowing to the plate supply. These decoupling networks may be employed in control grid, screen-grid, or plate circuits. Circuit $L3$–$C6$ is the tuned primary circuit of the second i. f. transformer $T2$. The secondary circuit $L4$–$C7$ is coupled to the primary, and is the input circuit of the next tube, which may be another i. f. amplifier or the second detector. The two resonant circuits of the second i. f. transformer $T2$ are tuned to the same frequency as the circuits in $T1$.

Since the i. f. amplifier is intended to furnish most of the gain of the superheterodyne, the number of i. f. amplifier stages used will depend on the sensitivity requirement of the receiving set. From one to three i. f. amplifier stages will be found in modern superheterodyne receivers.

The intermediate frequency of a superheterodyne will depend on two factors, the first being desired selectivity. The higher the intermediate frequency, the broader (or less selective) will be the tuning of the receiver. The second factor is the difference between the signal frequency and the intermediate frequency. It is not practical for the intermediate frequency to vary much lower than the signal frequency. Receivers used on the extremely high frequencies often use a fairly high intermediate frequency, the most common being between 456 and 465 kilocycles. Frequencies as low as 85 kilocycles, and as high as 12000 kilocycles, are often found in special purpose receivers.

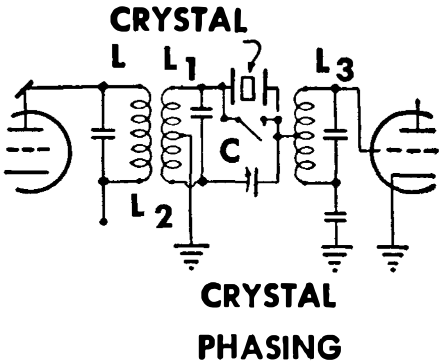


Figure 106.—Typical crystal-filter circuit.

If extremely sharp tuning is required a piezoelectric quartz crystal can be used as a crystal filter in the i. f. amplifier. The crystal acts like a tuned circuit but is many times more selective than those made of coils and capacitors. The crystal will only operate at one frequency determined by the thickness of the crystal. A typical crystal-filter circuit used in communication receivers is shown in figure 106. Unless you take steps to balance it out, the small capacitance between the metal plates of the crystal holder will bypass undesirable signals around the crystal. Balancing is carried out by taking a voltage from the center-tapped coil $L2$, 180° out of phase with the signal voltage, and applying it through the crystal-phasing capacitor C so that it bucks or neutralizes the undesired signal. The balanced-input circuit may be obtained through the use of a split-stator capacitor, or by the use of a center-tapped coil as in figure 106. The output of the crystal filter is applied to a tap on $L3$. This is the input circuit of the next stage, which provides the proper impedance match. Closing the switch across the crystal shorts the crystal-filter circuit, leaving an ordinary i. f. stage.

Noise limiters are used occasionally in the i. f. circuits of superheterodynes to suppress strong impulses of short duration, such as interference from sparking motor contacts or atmospheric static. In one such noise limiter circuit, a part of the intermediate frequency is diverted along a path paralleling the regular i. f. amplifier. It reaches a special detector tube which is so heavily biased that the i. f. signal is stopped at this point. If a sudden sharp pulse raises the detector tube above cut-off, the pulse will pass through, and will be fed back out of phase, thus blocking the sudden pulse which will be trying to pass through the regular i. f. amplifier.

R. F. Amplifiers

An r. f. amplifier is not essential in a superheterodyne, but it is a valuable addition for this reason—if the converter stage were connected directly to the antenna, unwanted signals might be received. These unwanted signals are called images. Since the mixer stage produces the intermediate frequency by heterodyning two signals whose frequency difference equals the intermediate frequency, any two signals whose frequencies differ by the intermediate frequency will produce an i. f. signal. For example, if the receiver is tuned to receive a signal of 2000 kilocycles and the oscillator frequency is 1500 kilocycles, an i. f. signal of 500 kilocycles will be produced. However, a signal of 1000 kilocycles finding its way into a mixer will also produce an i. f. signal of 500 kilocycles. Therefore, some method must be used to keep these unwanted signals, or images, out of the mixer stage. The extra selectivity provided by an r. f. amplifier is the solution. Since the r. f. amplifier greatly amplifies the desired signal, and does not amplify the image, the possibility of image interference is reduced considerably.

Most superheterodyne receivers are equipped with at least one r. f. amplifier stage. When used in a superheterodyne receiver, r. f. amplifiers are called preselectors.

Beat Frequency Oscillators

To receive c. w. signals on a regenerative detector, you will have to make the detector oscillate at a frequency slightly different from that of the incoming signal to produce (by heterodyning) an audible signal. In superheterodyne receivers, this is made possible by a separate oscillator, known as the beat-frequency oscillator, which is tuned to a frequency that differs from the intermediate frequency by an audible amount. For example, a beat-

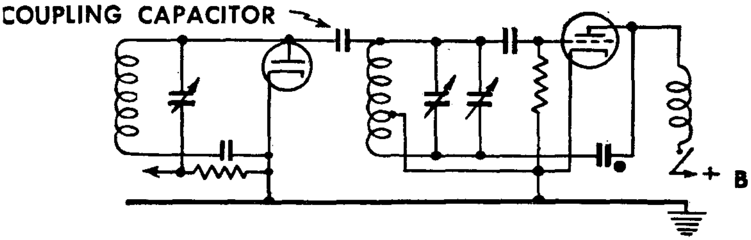


Figure 107.—A b. f. o. coupled to second detector of a superheterodyne.

frequency oscillator tuned to 501 kilocycles will produce a beat note of 1 kilocycle, an audible frequency when heterodyned with a 500 kilocycle i. f. signal. The output of this oscillator is coupled to the second-detector stage of the receiver.

A b. f. o. circuit is shown in figure 107. A switch and a frequency control are usually located on the front panel of the receiver to turn on the oscillator stage and to control the frequency, or pitch, of the audible signal.

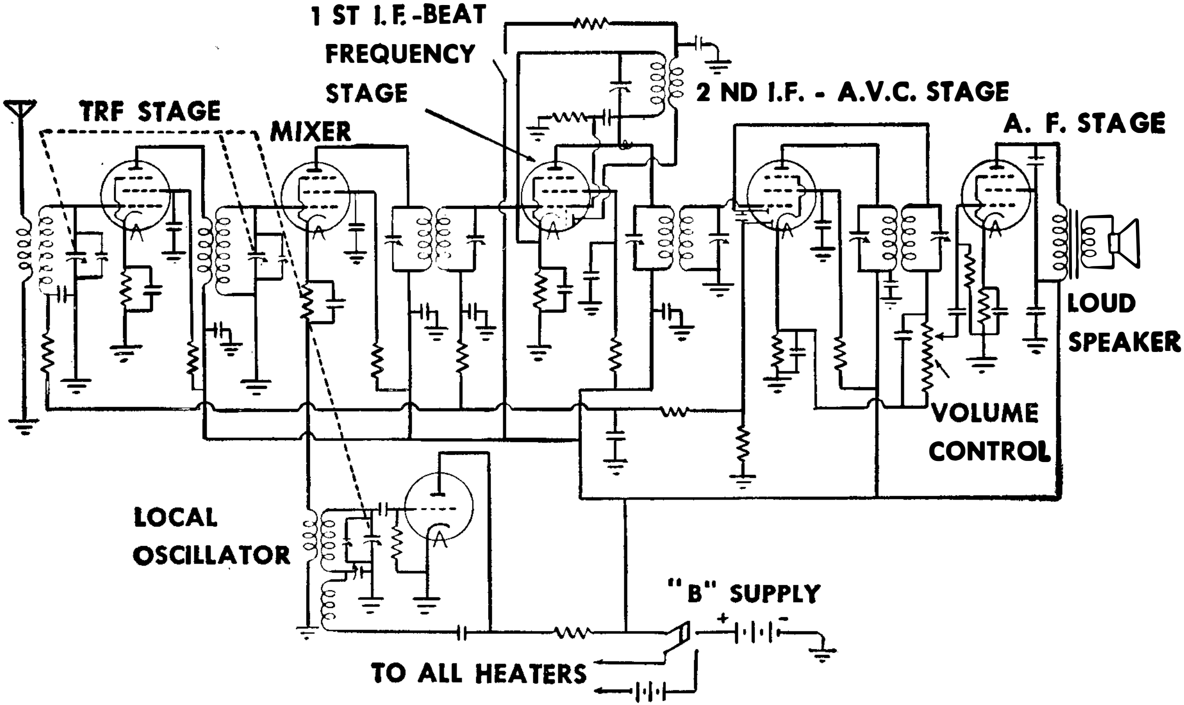


Figure 108.—Superheterodyne receiver.

Second Detectors

The detectors used in superheterodyne receivers to detect, or demodulate the intermediate frequency are of the same general types as those employed for t. r. f. receivers. Automatic volume control is widely used in superheterodyne circuits. The a. v. c. voltage may be applied to any or all of the stages before the second detector except the local oscillator.

Audio Amplifiers

The a. f. amplifiers used in superheterodyne receivers follow the same general principles as those employed in t. r. f. receivers. The desired power output is the main consideration.

SUPERHETERODYNE CIRCUIT

The circuit diagram of a six-tube battery-operated superheterodyne receiver is shown in figure 108. This receiver has one stage of tuned r. f. preselection (r. f. amplification), a triode acting as a local oscillator, a pentagrid mixer, two stages of i. f. amplification, a diode supplying voltage for delayed automatic volume control, a diode detector, and a pentode a. f. power-output stage feeding into a loud-speaker. The heater supply and *B* supply (plate voltage) are furnished to the various stages by batteries when the double-pole single-throw switch is closed. The amplifier tubes obtain their bias from the cathode resistor in the cathode circuit of each of the five tubes. The dotted lines connecting the three tuning capacitors indicate that these variable air capacitors are ganged. Small trimmer capacitors are connected in parallel with each of the ganged tuning capacitors for proper alinement of the receiver. The first i. f. stage uses a complex tube known as a triode-pentode. The pentode section of the tube functions as a straight-forward i. f. amplifier, and the triode section, operating as an oscillator, can be switched into the circuit to provide a

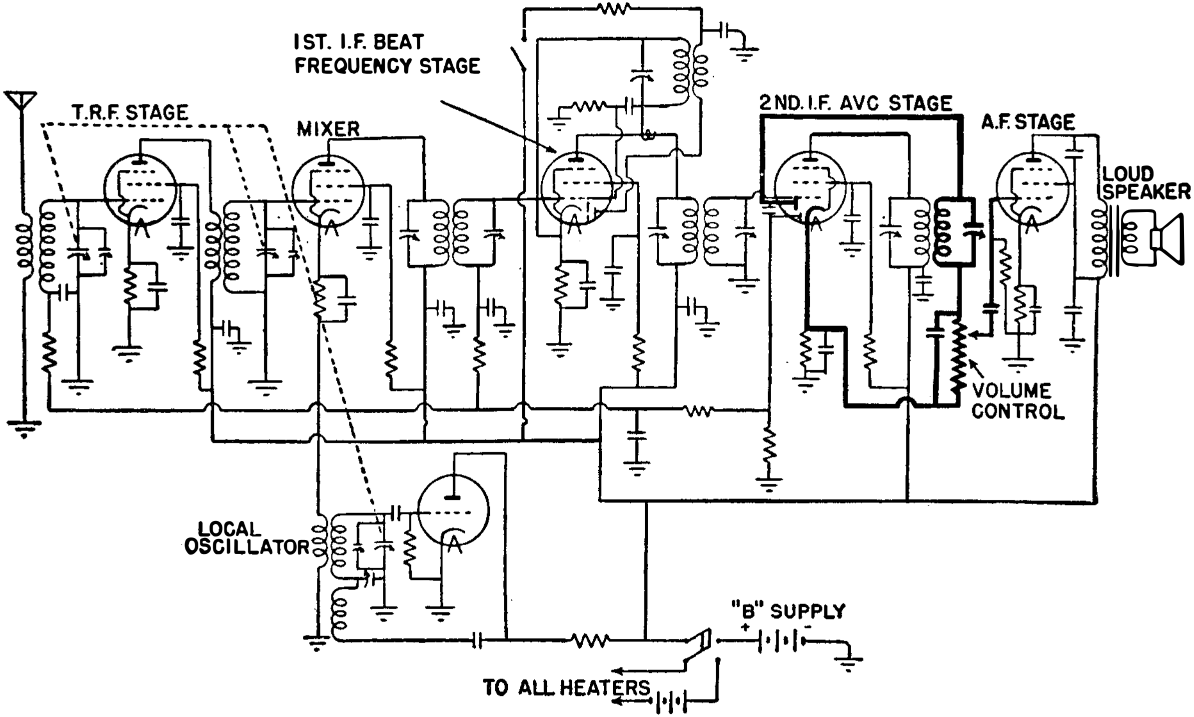


Figure 109.—Second detector circuit shown in heavy lines.

Restricted

heterodyne action for the audible reception of c.w. signals. The second i. f. stage combines several functions into one tube, known as a duplex-diode pentode. This tube contains a pentode i. f. amplifier and two diodes, one diode acting as straight signal detector, and the other supplying a rectified a. v. c. voltage. Figures 109 through 112 reproduce this same superheterodyne receiver diagram with various circuits emphasized to facilitate study.

In figure 109, all parts of the superheterodyne circuit relative to the second detector are denoted by heavy lines. A single diode (in the duplex-diode triode tube) supplies an audio-frequency signal voltage across the variable resistor, or volume control. Any portion of this voltage can be fed to the pentode a. f. power amplifier, and the level set by the volume control will be maintained by action of the delayed automatic volume control.

In figure 110, the delayed a. v. c. circuit is shown in heavy lines. The rectified signal voltage necessary for the operation of an a. v. c. circuit is obtained from the second diode of the duplex-diode triode. It is passed through isolating resistors, filtered by action of the r. f. bypass capacitors, and applied to the grids of the first r. f. amplifier stage and the first i. f. amplifier stage.

In figure 111, the local oscillator circuit is shown in heavy lines. The tuned circuit, which determines the frequency of the local oscillations, is composed of a fixed coil and a variable amount of capacitance, consisting of a variable air-tuning capacitor, an adjustable trimmer capacitor in parallel with the tuning capacitor, and an adjustable padding capacitor in series with the tuning capacitor.

In figure 112, the b. f. o. circuit is shown in heavy lines. The pentode section of the first i. f. amplifier tube, a triode-pentode, functions as a normal i. f. amplifier when the b. f. o. power switch is open. When this switch is closed, the pentode continues to operate as an i. f. amplifier, but oscillations take place in the triode section of

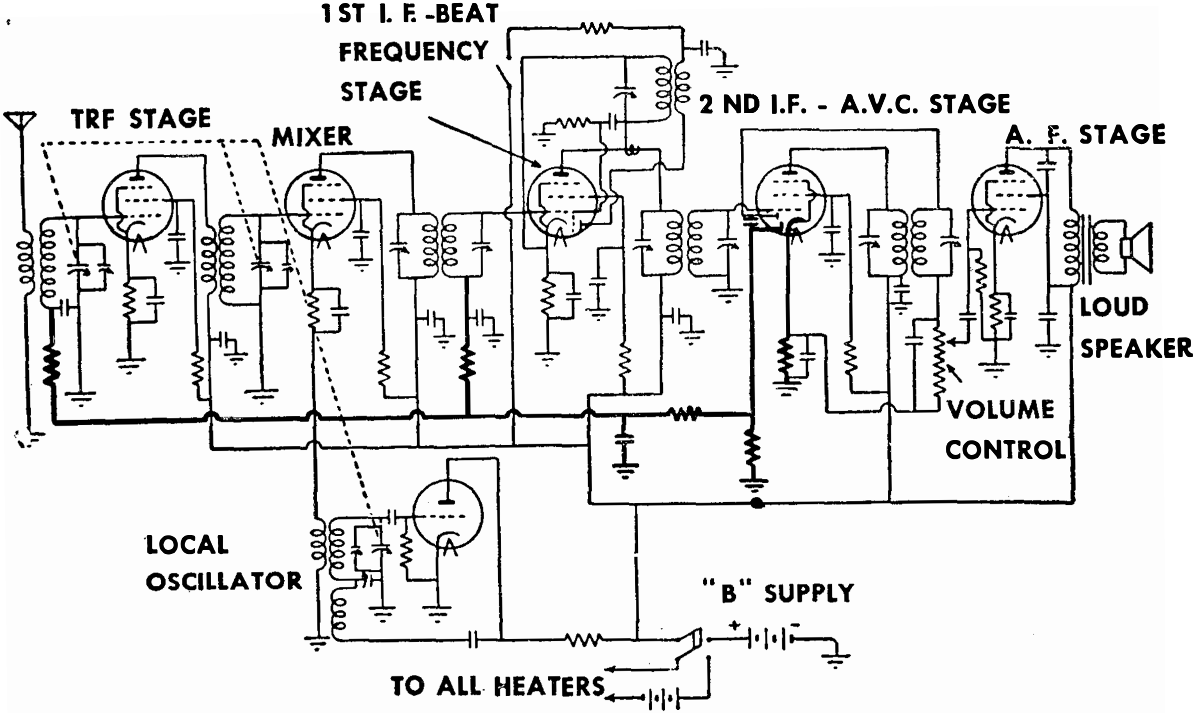


Figure 110.—Delayed a. v. c. circuit shown in heavy lines.

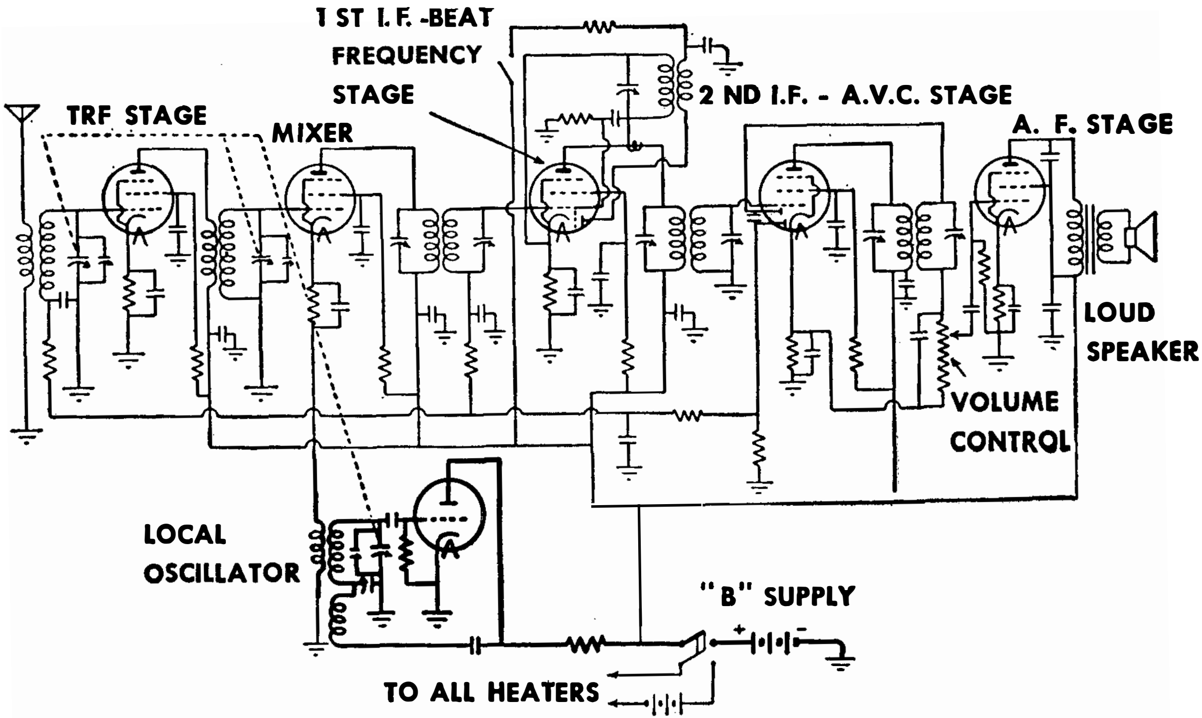


Figure 111.—Local oscillator shown in heavy lines.

Restricted

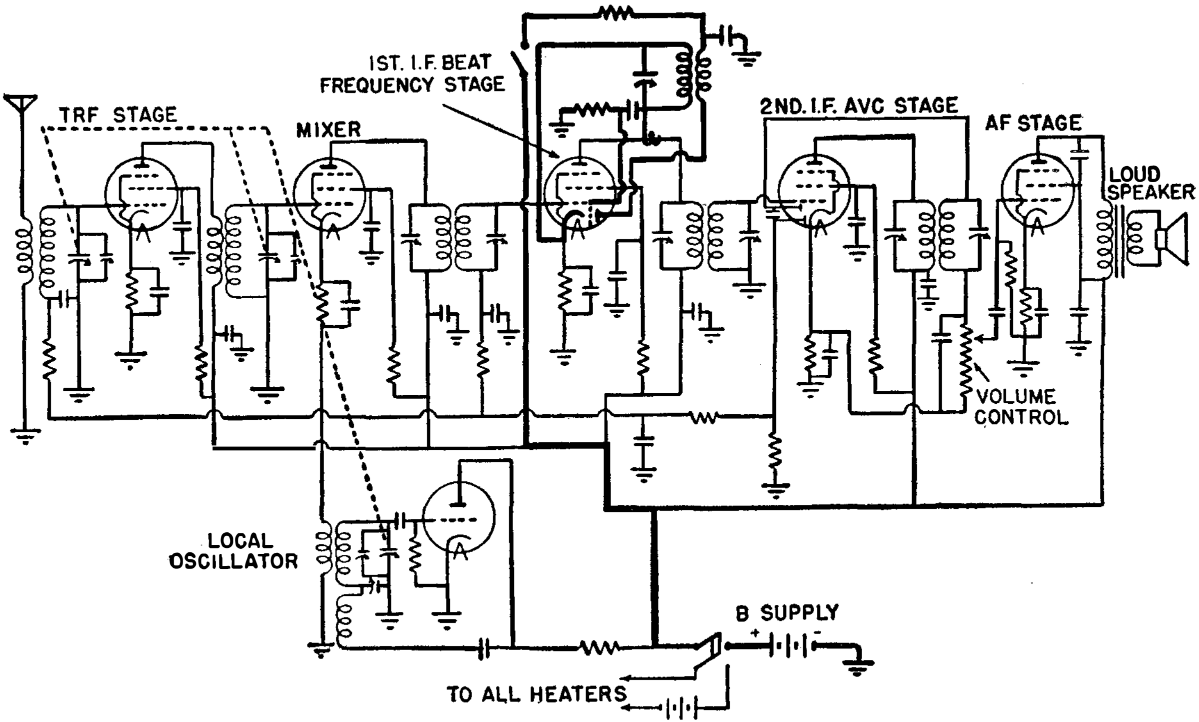


Figure 112.—Beat frequency oscillator for c. w. reception shown in heavy lines.

Restricted

the tube at the frequency of its external tuned circuit. By using a small variable capacitor, the frequency of this tuned circuit can be altered for different incoming signals, so that the local oscillations produced in the regenerative circuit are only SLIGHTLY different in frequency from the incoming signal. When these two frequencies are mixed in the first i. f. amplifier stage, there is a heterodyne action producing an audible signal which can be used for c. w. reception.

TYPICAL SUPERHETERODYNE RECEIVER

You will find a complete schematic diagram of a typical superheterodyne in figure 113. This receiver is operated from 110 volts alternating current and uses eight vacuum tubes. The r. f. signal voltage from the antenna circuit is amplified by a pentode r. f. amplifier stage. Another radio frequency generated in the local oscillator stage is mixed with the signal voltage in the pentagrid mixer stage to create an i. f. carrier. This intermediate frequency is amplified by a pentode i. f. amplifier stage, and is then detected by the diode detector section of a duplex-diode triode. The resulting a. f. signal is applied to the triode section of this complex tube which operates as an audio-frequency voltage-amplifier stage. This signal is further amplified by a push-pull audio-frequency power-amplifier stage of two pentodes, and then is fed to the loud-speaker. High voltage direct current for the plates, and low voltage alternating current for the heaters of the vacuum tubes are obtained from the power supply stage, which uses a full-wave rectifier circuit. You should note that every tube and circuit element in figure 113 has an identifying number. To facilitate a more thorough analysis of the set, the signal is traced through the receiver from the antenna to the speaker.

Assume that the receiver is tuned to a 1000-kilocycle signal and that the i. f. amplifier frequency is 465 kilocycles. The signal is picked up by the antenna and fed

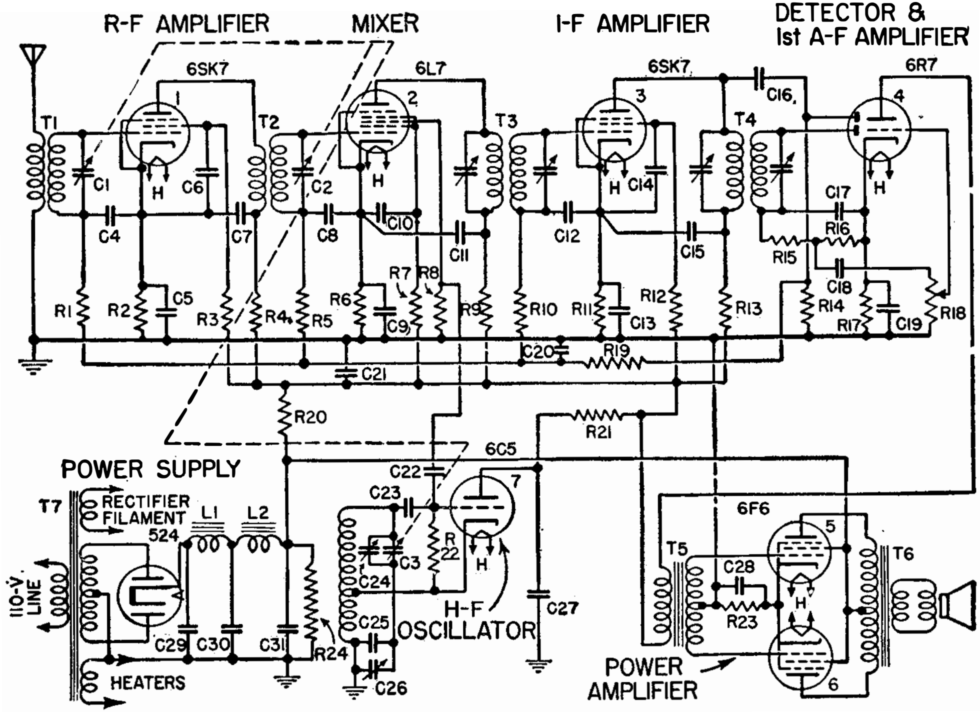


Figure 113.—Circuit diagram of a superheterodyne receiver.

to the grid of the r. f. amplifier tube (6SK7) through the r. f. coupling transformer T_1. The signal is then amplified by the tube and fed to the r. f. coupling transformer T_2. It is then applied to the control grid (grid 1) of the mixer tube (6L7).

The grid circuits of the r. f. and mixer stages are both tuned to the 1000-kilocycle signal by a single dial controlling the ganged capacitors C_1 and C_2. C_4 is a bypass capacitor for the grid decoupling resistor R_1. R_2 is the cathode biasing resistor and C_5 the bypass capacitor for R_2. R_3 is the screen grid voltage-dropping resistor and C_6 is the bypass capacitor for R_3. R_4 and C_7 constitute the plate current filter which prevents the r. f. signal from feeding back through the power supply to ground and thereby producing common coupling between stages.

The high-frequency oscillator (6C5) must generate oscillations that are 465 kilocycles higher in frequency than the r. f. carrier. It is tuned by C_3 (which is ganged with C_1 and C_2) to 1465 kilocycles. C_{24} is a trimmer for C_3 and C_{26} is a trimmer for C_{25} which is the padder capacitor used to make the oscillator track with the r. f. amplifier. R_{22} is the oscillator-biasing resistor and C_{23} is a blocking capacitor used to prevent the oscillator inductor from shorting R_{22}. R_{21} is the oscillator plate voltage-dropping resistor and C_{27} is the bypass capacitor for R_{21}. C_{27} also serves as a blocking capacitor to prevent shorting the plate voltage to ground.

The high frequency voltage is injected into the electron stream of the mixer tube on grid 3. R_8 is the injector grid-biasing resistor and C_{22} is the coupling capacitor for the oscillator. The 1000-kilocycle signal and the 1465-kilocycle signal are mixed in the electron stream of the mixer stage. The i. f. stage functions in the same way as the r. f. stage, except that it always works at the intermediate frequency and is much more efficient. The i. f. transformers T_3 and T_4 are fixed-tuned to the 465-kilocycle intermediate frequency, and require occasional checking for correct alinement. The lower diode section of tube 4 (6R7) is the detector, with R_{15} and R_{16} as the detector load resistor. C_{17} is the r. f. bypass capacitor. With R_{15} it forms an r. f. filter to prevent the r. f. component of the signal from feeding into the a. f. section through the blocking capacitor C_{18} and the volume control R_{18}.

The audio-signal voltage developed across R_{16} also appears across the volume control R_{18}. All or a portion of this voltage, depending on the setting of the variable arm, is fed to the grid of the first audio amplifier (triode section of tube 4). R_{17} is the bias resistor for the first a. f. amplifier, and C_{19} is its bypass capacitor. The i. f. voltage from the plate of the i. f. amplifier tube is fed through the blocking capacitor C_{16} to the upper diode plate, which rectifies the signal voltage to develop the a. v. c. voltage R_{14} is the a. v. c. diode load resistor. The d. c. voltage developed across this resistor is in series with the r. f. amplifier, mixer, and i. f. amplifier grid circuits. It is applied to the grids through the a. v. c. filter resistor R_{19}. R_{19} and R_{20} act as a filter to eliminate any audio component from this voltage, and thus prevent the grid bias of these tubes from fluctuating at an a. f. rate.

The output of the first a. f. amplifier is fed to the grids of the push-pull amplifier through the interstage-coupling transformer T_5. R_{23} is the bias resistor for both of these tubes and C_{28} is its bypass capacitor. The output of the power amplifier is fed to the voice coil of the speaker through the output (matching) transformer T_6. T_7 is the power transformer, tube 8 the power rectifier, L_1 and L_2 the filter chokes, C_{29}, C_{30} and C_{31} the filter capacitors, and R_{24} the bleeder resistor.

ALINING A SUPERHETERODYNE RECEIVER

The intermediate frequency stages, the local oscillator, and the preselector stages of a superheterodyne receiver must be correctly tuned or alined before the receiver will function properly. The steps in the alinement procedure differ for each type of receiver, but certain practices are common to most types.

To aline a superheterodyne, you will need a test oscillator, an output meter, and nonmetallic alining tools. Some receivers require the use of a dummy antenna to couple the test oscillator to the receiver.

Your first step is to tune the intermediate frequency stages to the correct frequency.

1. Turn off the a. v. c. If you leave it on its action will prevent you from knowing when the stages are tuned sharp.

2. Turn the volume control wide open.

3. Connect the output meter across the voice coil of the speaker. If the receiver has a built-in output meter, you will not need to use a separate meter.

4. Connect the oscillator to the control grid of the mixer tube.

5. Set the test oscillator to the correct intermediate frequency. Turn on the audio modulation.

6. Tune the last intermediate frequency transformer for maximum signal as indicated on the output meter. If the output exceeds normal range of the output meter, reduce the gain on the test oscillator.

7. After the primary and secondary coil of the last intermediate frequency transformer have been tuned, tune the transformer next in line, and then the next until all i. f. transformers have been tuned sharp.

If the intermediate frequency stages are badly out of alinement, you will have to connect the test oscillator to the grid of the last intermediate frequency tube and tune the last transformer. Then connect the test oscillator to the grid of the next tube back and tune the output transformer. Continue this process until all stages have been tuned.

After this preliminary alinement has been completed, connect the test oscillator to the grid of the mixer tube, and repeat the tuning procedure.

Remember—always tune the last stage first.

The next step is to tune the oscillator:

1. Disconnect the receiver antenna. Connect the test oscillator to the receiver antenna through a dummy antenna, as described in the receiver instruction book.

2. Set the test oscillator to a frequency near the middle of the frequency band to which the receiver is tuned. For example, if the receiver is operating on the 3 to 4.5 mc. band, set the test oscillator at approximately 3.7 mc. Be sure the frequency you select is not the frequency of some station or you will get interference with your tuning.

3. Set the receiver dials at about the same frequency as the test oscillator.

4. Adjust the oscillator padder for maximum output as indicated by the output meter. If the signal is strong enough to overload the meter, turn down the gain of the test oscillator. When this is done, the oscillator is tuned to the intermediate frequency above the r. f. input signals.

The final step is to adjust the trimmer condensers.

1. Open the tuning condensers as wide as possible. This is necessary if sharp adjustments of the trimmers are to be obtained. When the condensers are wide open the capacity of the trimmer is near that of the tuning condenser, so any adjustment in the trimmer capacity will be a large percentage of the total capacity.

2. Set the test oscillator to a frequency that will produce an output signal indicated by the meter.

3. Adjust the trimmer condensers on each tuning condenser, including the oscillator, until maximum signal output is obtained.

4. Disconnect the test equipment, connect the antenna, and your receiver is ready to go.

If the receiver has several frequency bands, the alinement procedure will have to be repeated for each band.

Accurate alinement of a receiver is a job that requires careful work. A poorly alined receiver will lose 50 percent of its sensitivity.

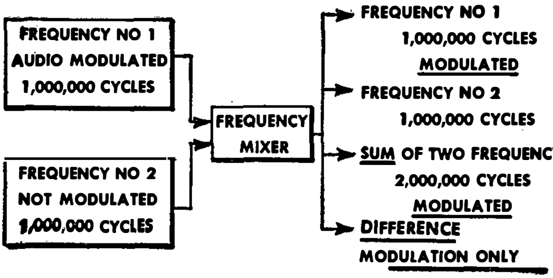


Figure 114.—Heterodyne detection.

THE HETERODYNE PRINCIPLE AND DETECTOR

You can use the heterodyne principle to obtain detection. This is shown in figure 114. Frequency No. 1 is an audio-modulated million-cycle carrier wave, and frequency No. 2 is an unmodulated million-cycle carrier wave. The two frequencies are fed to a mixer tube.

The output frequencies will be—

No. 1.—1,000,000 cycles, modulated.

No. 2.—1,000,000 cycles, unmodulated.

1+2.—2,000,000 cycles, modulated.

1—2.—Zero cycles, modulation only.

In this example, the radio frequencies are equal. When frequency 2 is subtracted from frequency 1, only the modulation remains. A condenser in the output from the mixer will bypass the two original frequencies and the sum frequency to ground, leaving only the difference frequency as an audio carrier wave.

RADIO DIRECTION FINDERS

A radio direction finder—RDF—is a radio receiver with a DIRECTIONAL LOOP ANTENNA. You use an RDF to obtain the bearings of radio broadcasting stations in the same manner that the quartermaster uses a pelorous to obtain sights and bearings on buoys.

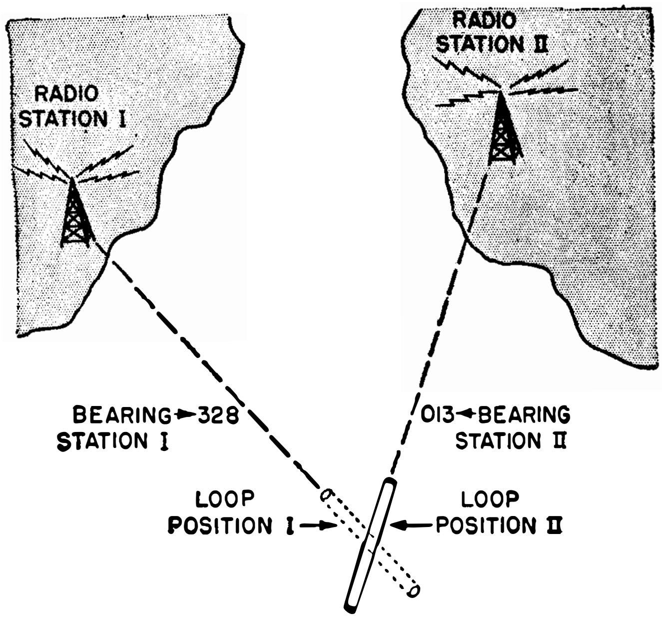


Figure 115.—How a loop antenna is used to obtain bearings of broadcasting stations.

The loop antenna will pick up more field energy and will pass stronger signals to the receiver when the edges of the loop are pointed toward a broadcasting station, but will pass minimum signals to the receiver when the FLAT FACES of the loop are turned toward the station.

In figure 115, the strongest signal from station I is sent to the receiver when the loop is in position I. A line drawn through the two edges of the loop indicates the bearing to station I to be 328°.

The loop is then rotated until a maximum signal from station II is received. The position of the loop indicates this station to bear ∅13. The intersection of the bearing lines 328 and ∅13 gives you your position.

The radio direction finder has uses other than to determine your own position. When an enemy ship breaks

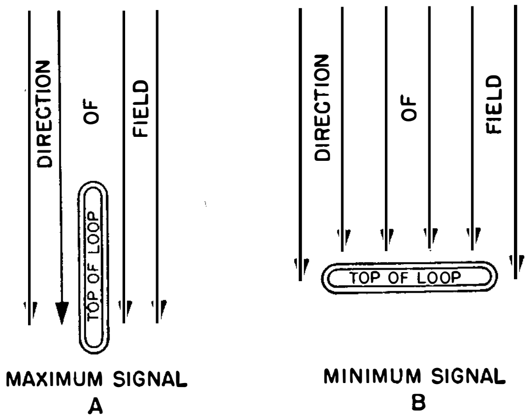


Figure 116.—Maximum and minimum signals with a loop antenna.

radio silence, the RDF can be used to determine his position. If two or more RDF several miles apart pick up the enemy signals, the approximate range and bearing of the enemy can be determined.

HOW THE DIRECTIONAL LOOP ANTENNA WORKS

The loop is either a circular or a rectangular coil of wire wound on a frame of nonmagnetic material. The loop is made resonant by connecting a variable condenser across the ends of the windings.

When either edge of the loop is turned TOWARD a broadcasting station, a voltage is induced in the FORWARD edge of a fraction of a second before it is induced in the FOL-

LOWING edge. Thus, the signal voltage will ADD, and the resultant voltage sent to the receiver will be MAXIMUM.

When the flat FACES of the loop are turned toward a broadcasting station, EQUAL and OPPOSITE voltages are induced in the two sides of the loop. These two voltages cancel each other, and the resultant signal sent to the receiver is MINIMUM.

Figure 116*a* shows the position of the loop when a maximum signal is sent to the receiver. The signal sent to the receiver is minimum when the loop is in the position indicated by figure 116*b*.

THE INDICATOR

Because your ear is a poor judge of signal strength, accurate bearing determination requires more delicate devices than the combination of a loud-speaker and your ear.

Older types of RDF—the DP series—use an output meter to indicate when the signal received is maximum. This meter is an a. c. voltmeter connected across the output of the receiver.

New models—the DAQ, for example—use cathode-ray tubes to indicate the bearing of the station. This new device has the advantages of greater accuracy and higher sensitivity.

SENSE DEVICES

A loop antenna will send equally strong signals to the receiver from broadcasting stations BEHIND as well as in FRONT of the loop. If you pick up a station that APPEARS to bear 1ØØ, the station may be located either at bearing 1ØØ or at 28ØØ (1ØØ + 18Ø).

To eliminate the guesswork, a SENSING DEVICE is added to the loop to determine whether the station is AHEAD or BEHIND the loop. This device is a NONDIRECTIONAL antenna, inductively-coupled to ONE leg of the loop, as illustrated in figure 117.

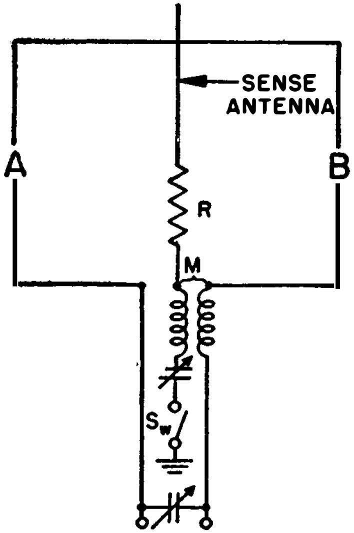


Figure 117.—Loop antenna with a sensing antenna.

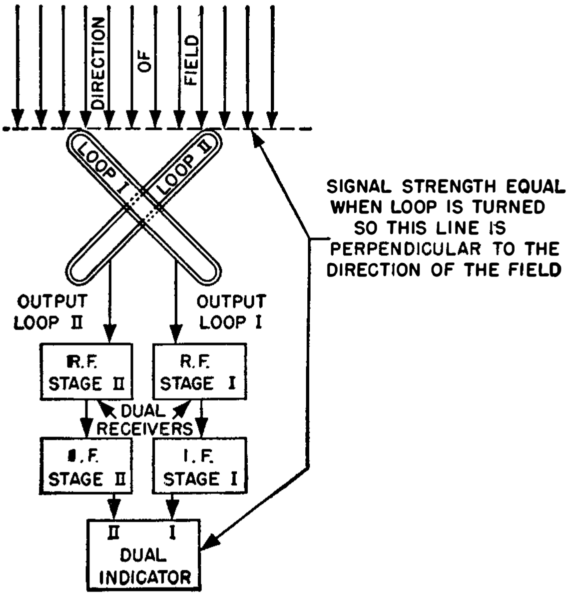


Figure 118.—Operation of the double loop.

When switch S_w is closed, the voltage induced in the sense antenna is ADDED to the voltage induced in leg *B*. Since the voltage induced in leg *B* is subtracted from that induced in leg *A*, the sense antenna effectively reduces the strength of the signal in leg *A*.

Thus, if leg *B* is pointing TOWARD the station, the magnitude of the signal is INCREASED when the sense button is pressed. But if leg *A* is pointing TOWARD the station, the strength of the signal sent to the receiver is REDUCED when the sense switch is closed.

If the signal from a station with an apparent bearing of Ø9Ø is DECREASED when the sense button is pressed, the station is actually at bearing 27Ø (Ø9Ø + 18Ø). But if the strength of the signal INCREASES when the button is pressed, the station is located on the original indicated bearing of Ø9Ø.

ACCURACY OF RADIO DIRECTION FINDERS

Accuracy of bearing determination is one of the weakest points in radio direction finders. Of the many devices used to increase accuracy, the DOUBLE LOOP is the most successful.

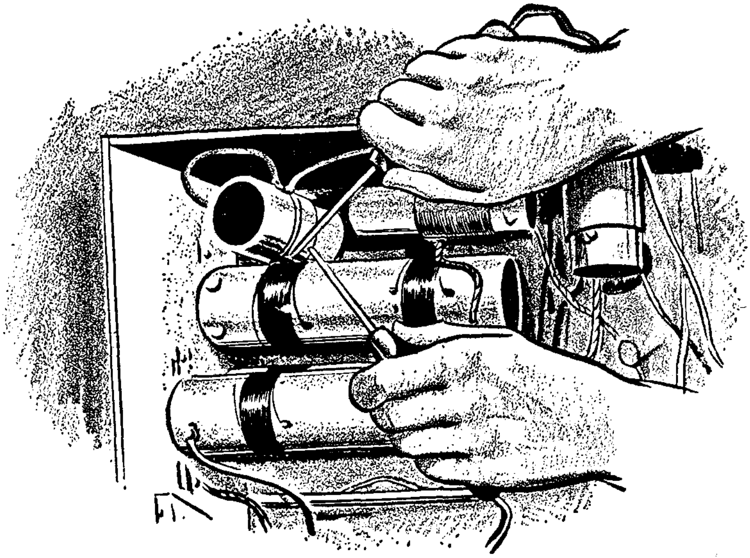
The double-loop device consists of two loops mounted at right angles to each other. Each loop has its own receiver. The output of the receivers is fed into a DUAL INDICATING SYSTEM.

The bearing of the station is not read when the signal from either loop is maximum. Instead, the bearing is read when the signal strength from the two loops is EQUAL. This system of matching the signals from the two loops permits greater accuracy of bearing determination than is possible with a single loop.

There are several types of radio direction finders in use in the Navy today. Instruction books which come with the RDF gear are the best sources of technical and operational information concerning the type of equipment installed aboard your ship.

QUIZ

1. What type of volume control is widely used in superheterodyne receivers?
2. What are r. f. amplifiers called when used in superheterodyne receivers?
3. What determines the number of i. f. amplifier stages used in a superheterodyne receiver?
4. What do the combined circuits of the oscillator stage and mixer stage of a superheterodyne receiver form?
5. To aline a superheterodyne receiver, what equipment is necessary?
6. Name the three stages of a superheterodyne receiver which must be correctly tuned or alined before the receiver will function properly?
7. What is a pentagrid converter?



CHAPTER 7

TESTING EQUIPMENT

METERS

To give your equipment the care it needs, you'll have to know how to handle meters and testing equipment. Proper use of voltmeters, ohmmeters, and other testing instruments will not only speed up repair but also protect your equipment from injury due to improper handling.

One of the most common radio testing instruments is the voltmeter. You should use one with a sensitivity of not less than 1,000 ohms per volt when available. The higher the sensitivity, the less error from shunting effects. The direct current voltmeter that comes with the model OE analyzing equipment has a sensitivity of 20,000 ohms per volt up to and including the 250-volt range.

Some instruments use electronic voltmeters which have a sensitivity of 1,000,000 ohms per volt and are ideal for use in radio service work. You should remember that when using voltmeters or ammeters with multiple scales, you always use the range that will produce the nearest approach to full scale deflection.

Alternating current voltmeters of the rectifier type should be used when measuring a. c. voltages. The moving iron type meter draws substantially more current than the rectifier type and is not as accurate. The a. c. voltmeter that is a part of the OE equipment has a sensitivity of 250 microamperes full scale, but is so shunted as to have a sensitivity of 1,000 ohms per volt. Capacity measurements from 0.0001 to 200 microfarads may be taken with this meter.

The ohmmeter or continuity tester, is also a valuable aid in service work. One of the greatest errors in the use of the ohmmeter is failure to zero center the needle with the test prods short-circuited before making a measurement. This error is especially noted when shifting from one scale to another. When you use this instrument, take the range that will give the nearest midscale deflection.

Output meters, which are merely a. c. voltmeters, usually of the rectifier type calibrated to read in decibels, are very advantageous, especially when taking sensitivity measurements. Their use in comparing signal strengths in terms of decibels is also important. Normally, any good rectifier type a. c. voltmeter can be substituted for an output meter in most service work.

The signal generator, alinement or test oscillator is another very important instrument which is invaluable for use in all service work. This instrument furnishes a radio frequency signal, either c. w. or modulated, of known calibrated value and frequency as a substitute for a normal signal. It should be used when you make receiver alinement and sensitivity measurements.

VACUUM-TUBE TESTING

The function of an amplifier tube is to take a small voltage change on its grids, amplify this effect, and pass it along to succeeding tubes or circuits. This function can be used to test the efficiency of a tube. The better type vacuum-tube testers use this function to obtain a figure for comparison with a known good tube, since its standards were set by the manufacturer. Rectifier tubes, including diodes, are normally tested by measuring the amount of current the tube will pass at a given plate voltage. A test for short-circuited elements is also essential and should be made before proceeding with the regular test.

In determining the efficiency of an amplifier tube, which is indicated by a measurement of its transconductance, the following test is performed: The proper operating voltages are placed on the various tube elements. An a. c. signal, adjusted to one volt, is impressed in series with the d. c. grid bias across the input, or grid circuit of the tube, and the value of resultant a. c. signal output in the plate circuit of the tube is read. An a. c. rectifier type of milliammeter indicates the change in plate current caused by the one-volt signal on the grid and is calibrated to read directly in micromhos. Rectifier tubes, including diodes, are tested by measuring the amount of current they will pass at a given plate voltage. All readings must be compared with a set of normal readings taken from the tube manufacturer's data to determine the exact condition of the tube. Some tubes, such as certain types of multipurpose tubes, can only be tested for a certain predetermined cathode emission.

Since many receiver failures are caused by defective tubes, some method of testing is necessary before proceeding with any further analysis of the receiver. Remember, a test of every tube is an important step in the servicing of a receiver.

POINT-TO-POINT RESISTANCE MEASUREMENT

The use of resistance measurements for receiver analysis became imperative as circuits became more complex. The unstable conditions encountered when voltages are checked while a receiver is operating, and the presence of well-hidden defects that cannot be located by voltage measurement have made the use of resistance tests mandatory.

The point-to-point system of resistance measurement of d. c. resistance between any two points in a receiver and the location of the trouble by interpretation of these resistance findings is the ultimate test given a receiver, even after the operating voltage test may indicate some defect.

The location of a defective circuit, such as an open or short circuit, or a substantial change in d. c. resistance, may be detected by testing between some common point of reference, such as the filament circuit of the rectifier tube, or the receiver chassis, to the various tube-socket connections throughout the receiver. In some cases you must isolate certain items to get direct readings. You must make a thorough study of the receiver circuits undergoing a test.

When you apply the point-to-point method of testing, it is a good idea to have a table of resistance values for the receiver in question. This table is to the point-to-point method what the table of voltage is to the voltage-analysis method of testing.

With the aid of the circuit diagram shown in figure 119, an example of the application of the point-to-point resistance-measurement method is given. Point *A*, which is the rectifier filament, and point of high voltage, and point *X*, the receiver chassis, are given as reference points. A systematic test of the various circuits of tubes 1 and 2 will consist of the measurement of the d. c. resistance between points *A* and *B*, *A* and *C*, *A* and *D*, *A* and *G,* and *A* and *H*. Measuring between points *X* and *F, X* and *D,* and *X* and *E* would complete the test with the exception of isolating certain items. Testing between points *B* and *G* would isolate the transformer winding *I*. Testing between points *G* and *H* would isolate

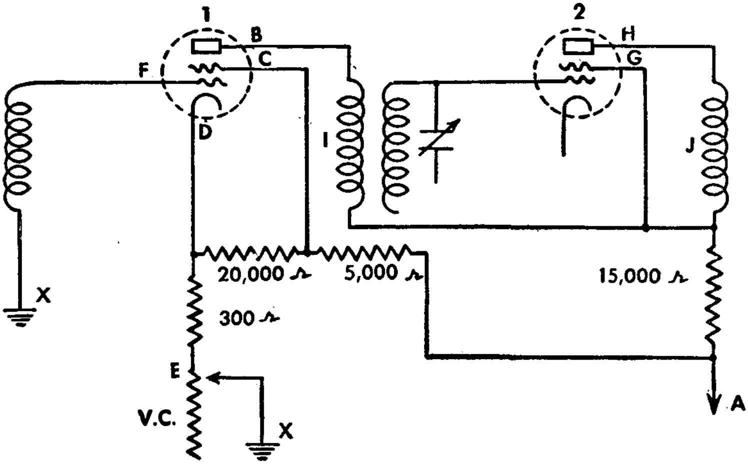


Figure 119.—Point-to-point resistance measurements.

the transformer winding *J*. Testing between points *X* and *D* with the volume control set to zero (maximum volume) would isolate the 300-ohm cathode resistor. You will note that all measurements are made from one of the two reference points to the tube-socket connections or between two tube-socket connections. Complete isolation of units to be tested is possible by careful selection of the testing points to avoid measuring shunt circuits.

While it is true that complete circuits use capacitors not shown in figure 119, capacitor defects which influence voltage will, in practically every instance, show up during a d. c. resistance test of the associated circuit. About the only exception to this rule is an open-filter capacitor in the power supply.

Any form of short circuit or high degree of leakage will influence the d. c. resistance between the respective points. It stands to reason that, if such a defect is located, it will be necessary to disconnect the capacitor and to repeat the test. The same is true in the case of the voltage test but there is danger of damage to the receiver if the system is operating during the test.

Pay special attention to electrolytic capacitors during a point-to-point testing. The polarity of the ohmmeter circuits must be correct with respect to the polarity of the capacitors. The shunting effect of these capacitors is negligible. The high values of capacity with comparatively low leakage resistance are generally used in shunt with very low values of resistance, hence have very little effect.

POINT-TO-POINT MEASUREMENT OF VOLTAGE AND CURRENT

When testing a receiver you should have a schematic and a wiring diagram of the equipment as well as a table of the various terminal and tube-socket voltages and currents. For equipment where such data is not available but properly operating duplicate equipment is available, you should see that you have complete data on the operative equipment and record it for future use. If no data and no duplicate equipment are available, reference must be made to a tube manual for data on proper operating voltage and current values for the various vacuum tubes and these used as a basis of test.

The point-to-point method of testing a radio receiver is primarily a voltmeter method. Using the receiver chassis or the negative high voltage (B minus) as a reference point, each circuit is considered individually and the voltage tested and recorded at progressive points toward each tube element. A sudden loss of voltage indicates an open circuit, a short-circuited capacitor, or a burned-out resistor, which can be individually isolated by further tests. An abnormal increase in voltage could indicate a shorted resistor or other nonfunctioning circuit component. Due to the necessity of removing tubes to take measurements when inaccessibility of the bottom of tube sockets prevents direct measurement, and for the more complicated multicircuit equipments, it is advantageous to first isolate the defective circuit by selective circuit analyzing. Final determination on the circuit so isolated may be made by the point-to-point method.

All receivers are built around the vacuum tube used as an amplifier, rectifier, detector, or oscillator. Whenever an open or short circuit occurs in the filament, plate, grid, or screen-grid circuit of a vacuum tube, it will have a definite effect on the voltage and current readings at these different tube elements. By using an analyzer, such as the Navy model OE, a rapid and accurate check on these circuits can be made by taking voltage and current readings at each socket with the tube still in the circuit. This is accomplished by using a socket selector unit which permits the extension of all circuits from any tube socket of a receiver to the block designed to mount on either of two voltmeters, which are parts of the OE equipment. The unit is so constructed that the current in, or voltage across any circuit, may be measured. Adaptors are provided for both the base unit and socket unit, which plug into these units and permit the insertion of 4, 5, 6, 7, 8, and octal base tubes into the selector and the plug into similar sockets with the same number of contacts. These adaptors are so designed that when inserted into the selector the inapplicable pin numbers are obscured and the circuit tracings on the face of the selector transferred to the proper socket points. The various tube circuits are merely patched with small patch cords, to the proper voltmeter or milliammeter scale and their values read on the meter.

FREQUENCY METERS

Principle of Operation

A frequency meter measures frequency of transmitters, receivers, and other oscillating circuits. It is a calibrated standard with which circuits may be compared to accurately determine unknown frequencies, or to adjust a circuit to a predetermined frequency.

Frequency meters are generally classified as absorption and heterodyne types. The former is an early type meter and was previously known as a wave meter. The modern heterodyne type consists primarily of an oscillating circuit.

In the heterodyne-type frequency meter, both the standard, and the circuit under measurement, must be oscillating. They are coupled sufficiently for the two generated frequencies to mix, and resonance is indicated by a zero beat. In continuous wave reception a signal can be heard by tuning the receiver on either side of a silence band or null point. When the received signal and the frequency of the oscillating receiver are the same, the mixing of the two creates a condition where no signal can be heard. This is known as the zero-beat point and tuning to either side will produce an audio tone equal to the difference in frequency of the two. This same principle is incorporated in all heterodyne-type frequency meters.

Frequency Measurements

To accurately measure the emitted frequency of an adjacent transmitter or oscillator, the frequency of which is approximately known, correct the heterodyne oscillator to the crystal check point nearest to the approximately known frequency with the modulation switch set to OFF, as previously explained. Determine the actual frequency (after loosely coupling the frequency meter pick-up wire to the source and turning the crystal switch to OFF) by turning the frequency meter tuning control to the zero-beat point found nearest the setting given for the appropriate frequency column in the calibration book. If the dial setting is not in the calibration book, use the interpolation table.

If the order of the frequency to be measured is absolutely unknown, it may first be determined to an approximation with the aid of an absorption-type wave meter. Determine the actual frequency as explained in the preceding paragraph.

When you wish to measure a frequency of remote origin, first tune the signal in on a radio receiver and note the approximate frequency from the receiver calibration. Correct the heterodyne oscillator of the frequency meter to calibration at the nearest crystal check point. Turn the crystal switch off; plug the phones into the receiver output jack, and loosely couple the frequency meter tuning control until the signal is heard in the phones.

If the signal in question is c. w. in character, tune the receiver to zero beat, and tune the frequency meter (modulation switch-off) to zero beat with the receiver.

If the signal is modulated, turn the frequency meter modulation switch ON, and adjust both the receiver and the frequency meter for maximum response.

In both cases, the frequency read from the appropriate column in the calibration book (for the resultant frequency meter dial setting) is the frequency of the signal in question. If the dial setting of the frequency is in the calibrated range but not listed in the book, use the interpolation table to find the correct frequency.

Crystal Calibrators

To accurately calibrate and check the calibration of a frequency meter for errors, a crystal-controlled oscillating circuit is utilized as a standard of comparison. The calibrator circuit is so designed that the output is very rich in harmonics of the crystal frequency and they may be used as calibrating points. By coupling the output of the calibrator into the frequency meter and comparing the two frequencies, an accurate calibration may be made. For example, if a calibrator using a 50-kc. crystal were used, it would be possible to get a check point every 50 kc. Knowing the approximate calibration of the meter, this affords excellent opportunity to plot a corrected calibration curve. In older type equipments the calibrator was a separate unit, but in modern equipment, the calibrator is a part of the frequency meter itself.

Operating Instructions

Before any frequency adjustments are made, the heterodyne oscillator should be corrected to calibration through comparison with the crystal oscillator at the crystal check point nearest to the frequency desired. Comparison between the crystal and heterodyne oscillator may be made at many points over the calibrated range through the use of the fundamental or harmonic frequencies of either or both oscillators. Comparison between the two oscillators is effected by rotating the heterodyne tuning control through a portion of the scale range corresponding to the crystal check point desired, and noting the beat notes heard in a pair of 600-ohm phones. (Be sure you set the modulation switch to the OFF position.)

To correct the heterodyne oscillator preparatory to setting it on any desired frequency within the calibrated range, proceed as follows:

1. From the high or low frequency chart on the front and rear covers of your calibration book, select the band for the desired frequency and set the frequency band switch to correspond.

2. From the frequency index, make certain which page

lists the desired frequency. The crystal check point nearest the desired frequency, together with its dial setting, will be noted in red at the bottom of the page (nearest the crystal check point).

3. Set the heterodyne oscillator scales to agree with this crystal check point dial setting (crystal and power switches ON, modulation OFF). A beat note will most probably be heard in the phones, as a complete absence of beat tone can result only from four possible conditions: (1) When the heterodyne oscillator is exactly on calibration; (2) when the heterodyne oscillator is so far off calibration that the beat frequency is above audibility; (3) when the modulation switch is ON; and (4) when the equipment is defective.

However, should no beats be heard, the two conditions that may exist can be determined by rotating the corrector dial until the beats become audible, and by noting the direction of change. If the third or fourth condition is the cause, no beats should be heard at any point in the complete heterodyne range.

4. With the heterodyne oscillator dials on the desired crystal check point setting, the heterodyne oscillator frequency should be adjusted as near to the crystal oscillator frequency as possible by rotation of the corrector dial only. Adjust the corrector to produce zero beat at the strongest beat point within its range. After you become familiar with the equipment, you will find that this adjustment can be precisely made to practically zero beat. This is possible because the design is such that all LOCKING-IN tendencies have been minimized and characteristic RUSHES, due to the rise and fall of the beat frequency peaks, are recognizable well below the lower limit of audible tone.

Transmitter Adjustments

Adjusting a transmitter to a desired frequency consists of zero beating the transmitter frequency with the proper heterodyne oscillator frequency. The comparison is effected by a pair of phones plugged into the phone jack located on the front panel of the frequency meter. The procedure is as follows:

1. Correct the heterodyne oscillator to calibrate at the crystal check point nearest the desired frequency, as previously explained (be sure the modulation switch is turned OFF).
2. Turn off the crystal switch.
3. Turn the frequency meter tuning control to the dial setting of the desired frequency, as given in the calibration book. If the desired frequency is in the calibrated range but not listed in the calibration book, consult the interpolation table. Do not disturb the corrector adjustment as made in 1 above.
4. Set the transmitter to the approximate frequency desired by reference to dial calibration or calibration chart of the transmitter.
5. With the frequency meter pick-up lead loosely coupled to the transmitter output, tune the transmitter to give an audible beat in the phones.
6. Adjust the r. f. coupling until you reach a comfortable signal level on the phones.
7. Tune the transmitter to zero beat with the frequency meter.

Receiver Adjustments

The method of adjusting a receiver to a desired frequency consists of tuning the receiver to the proper heterodyne oscillator output frequency, and making a comparison by the use of a pair of headphones connected to the receiver output circuit. The method varies with the character of signal reception involved.

C. W. Adjustments

To tune a c. w. receiver to a desired frequency proceed as follows:

1. Correct the heterodyne oscillator to calibration at the crystal check point nearest the desired frequency, as previously explained. (Be sure the modulation switch is in the OFF position.)

2. Turn off the crystal switch and transfer the phones from the frequency meter to the receiver output jack.

3. Turn the frequency meter tuning control to the dial setting of the desired frequency, as given in the calibration book. If the desired frequency is within the calibrated range, but not listed in the calibration book, use the interpolation table.

4. Set the receiver to the approximate frequency desired by reference to the dial calibration or calibration chart of the receiver.

5. With the frequency meter pick-up lead loosely coupled to the receiver antenna lead, tune the receiver to give an audible signal in the phones.

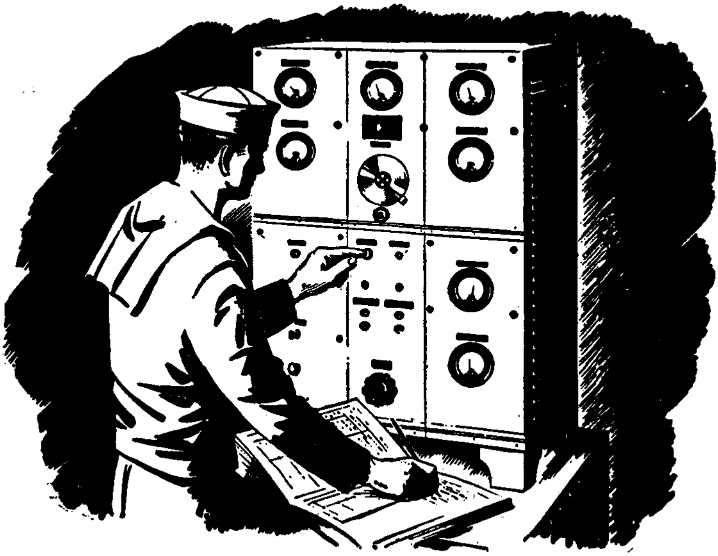
6. Adjust the r. f. coupling control to obtain a good signal level in the phones.

7. Adjust the receiver tuning to the side of the zero beat which results in best reception condition for the particular operator concerned.

When adjusting a m. c. w. receiver to a desired frequency, the procedure is the same as for c. w. except, instead of turning the modulation OFF, it is turned ON so a modulated tone will be heard in the receiver. Another thing, you should adjust receiver tuning for maximum response.

QUIZ

1. What is the purpose of a frequency meter?
2. What is one of the greatest errors in use of the ohmmeter?
3. Why is it necessary to have an understanding of the correct use of voltmeters, ohmmeters, and other equipments?
4. What type of voltmeters should be used when measuring a. c. voltage?
5. What is the signal generator used for?



CHAPTER 8

TRANSMITTERS

KNOW YOUR EQUIPMENT

Every Radioman first and chief must know how to operate and service radio transmitters. As you already know, operation means starting, and tuning transmitters to various desired frequencies, ready to be keyed. Servicing means more than preventive maintenance. It includes upkeep of the apparatus, location and analysis of various troubles, and the ability to promptly make necessary repairs.

All Radiomen must learn the fundamentals in order to perform their duties efficiently. In the case of the first class and chief, the bare fundamentals, of course, are not enough. A thorough knowledge of circuit design, for instance, is necessary to understand how a particular radio circuit should operate. Skill in performing your duties is acquired only by constant study of radio engineering principles, and the application of these to the equipments in your care.

INSTRUCTION BOOKS

The transmitter instruction book contains valuable information which is not always used to best advantage simply because it is not studied carefully. Instruction books are usually arranged in sections, one or more of which is used during the installation of the transmitter. Other sections describe normal operation and contain instructions for correct tuning. The remainder of the book is used while trouble-shooting and during upkeep operations.

The arrangement and content of the instruction book should be closely observed. It is not essential that you remember all the data it contains. Simply make mental notes, as you go through the book, of the purpose and use of each section. For instance, there may be a data sheet containing information about relay coils and contacts. Or, there may be a paragraph detailing the information which should accompany an order for a renewal part. Make a note of this, and the general nature of the data, for possible future use. The more familiar you are with the instruction book, the easier your work will be and the more time you can save in an emergency.

The schematic, wiring and interunit connection diagrams should be studied carefully. First make sure you can identify any part illustrated. Any part you cannot recognize on sight should be identified by consulting the parts list. Familiarize yourself with the system of symbols used. This is particularly important when a symbol has been assigned to each pair of contacts on a relay or switch. Sometimes several devices operate from the same control; the method of showing this on the diagram should be noted. Determine the best use to which the schematic, wiring and interunit connection diagrams can be put.

Many transmitters are built for operation from a variety of line voltages and power supply equipments. To make this flexibility possible it is necessary to use different resistance values in some circuits and, in others, to rearrange the circuits themselves. Where parts or connections must be changed for operation at different line voltages, the necessary changes are usually shown on the diagrams in the form of notes. Different manufacturers show these changes in different ways. Make sure you understand the method used on the diagrams for your transmitters.

LEARNING TO TUNE A TRANSMITTER

On the front or side of all Navy transmitters is a chart on which settings for each control for any frequency commonly used are posted. In addition, the instruction book contains a chart showing typical control settings for several frequencies throughout the range of the transmitter. The purpose of these charts is to enable any operator to reset the transmitter to a given frequency in the shortest possible time. The transmitter can be tuned to frequencies not shown on these charts by interpolating between these known settings.

The following discussion will give you a better idea of what is actually happening when you tune a transmitter to any given frequency. A large percentage of the troubles encountered in the r. f. circuits of transmitters are not due to failures of tubes or parts, but to improper tuning. This is particularly true when a transmitter is tuned to a frequency to which it has not previously been calibrated. Improper tuning will not only cause strong interference, but will result in general inefficiency of the circuits, heating of tubes, chokes, etc., and cause an unnecessary waste of time trying to locate the trouble.

As in most transmitter servicing problems, knowledge of the design of the apparatus is of great value. There are, generally speaking, three types of shipboard transmitters in use in the Navy at the present time: (1) High frequency transmitters (2000 to 18000 kc.) using continuously variable oscillator circuits of the electron-coupled type; (2) very high frequency transmitters using crystal-controlled oscillators; and (3) intermediate frequency transmitters (175 to 2000 kc.) using continuously variable oscillators which may be of the electron-coupled type or may be variations of the Colpitts circuit. The use of different type oscillator circuits, wide frequency coverage in one transmitter and the necessity of using poor and inefficient antennas result in the use of slightly different techniques in tuning these different types of transmitters.

INTERMEDIATE FREQUENCY TRANSMITTERS

The i. f. transmitters are the easiest to tune since there is little danger of tuning one of the stages to a frequency which is a harmonic of the oscillator frequency. Shipboard transmitters of this type usually consist of the oscillator circuit, one or more stages of intermediate amplification, the main power amplifier, and the antenna tuning system.

As previously mentioned, one type of oscillator used in i. f. transmitters is the Colpitts. A schematic of the Colpitts oscillator circuit is shown in figure 120. Instead of giving the magnetic field a push, it gives a shove directly to the electrons in the tank circuit.

The feed-back is made through condenser C_1. The tank circuit is formed by L_2 and C_2. The bias voltage is developed by R_3 and C_3.

The rise and fall of the plate potential due to the increase and decrease of the plate current, charges and discharges condenser C_1. The electrons from this give other electrons in the TANK CIRCUIT the shove that is needed to keep the oscillations going.

In the late model transmitters, plug-in arrangements have been provided for coupling the oscillator circuit to the frequency meter to facilitate accurate frequency adjustment. A jack is mounted on the front panel of the transmitter into which phones can be plugged in order to listen for a zero beat when tuning the oscillator

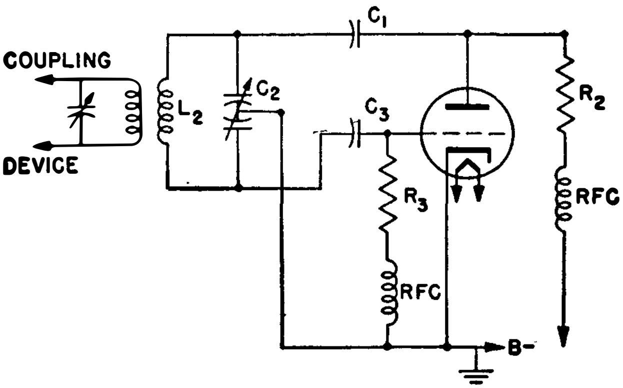


Figure 120.—Colpitts oscillator circuit.

to the frequency meter. In the older models these provisions were not made so it was necessary to provide a coupling lead and long phone cords. In many cases this coupling lead consisted simply of a loop of insulated wire placed on the oscillator compartment and connected to the proper terminal on the frequency meter. Coupling should always be made to the oscillator itself and not to one of the amplifier stages.

The frequency meter should first be tuned to the frequency desired at the output of the oscillator. In intermediate frequency transmitters the output frequency will usually be the same as the actual oscillator frequency even when an electron-coupled oscillator circuit is used. This is true because tuning the plate circuit of these oscillators to the same frequency as that generated in the oscillator section of the circuit does not cause enough reaction on the oscillator, at these intermediate frequencies, to affect the generated frequency. (Note—When these oscillators are used in high frequency transmitters the plate circuit is usually tuned to twice the generated frequency.) The oscillator should be brought to resonance by tuning to zero beat. The zone of silence may be rather broad at these frequencies. The oscillators should be set at the center of the silent zone. If greatest accuracy is desired the audio oscillator in the frequency meter should be used.

Once the oscillator has been accurately tuned to the desired frequency the amplifiers should be tuned to resonance. This is done by adjusting each plate circuit to the point where plate current is exactly at the bottom of the characteristic resonant dip. The bottom of the dip should be sharp and well defined and indicate that the tank circuit is tuned to resonance. The circuits of some transmitters include grid current meters. It will be found that when resonance is reached, as indicated by the plate current dip, grid current in the following stage will rise. In well-designed transmitters these two changes will take place almost simultaneously. However, if the bottom of the dip in plate current occurs at a setting widely different from that for maximum grid current in the following stage, the first amplifier should be tuned to resonance by watching the grid current meter in the following stage and tuning for a maximum reading. Maximum grid current then indicates that the amplifier plate circuit is operating at unity power factor. This applies when tuning ANY amplifier plate tank circuit to resonance. This process should be repeated in each stage in the transmitter.

Tuning curves for each amplifier stage and approximate dial settings for each control are included in instruction books. These data represent average values for many transmitters of the same type and are fairly accurate. They include control settings for a number of frequencies spaced throughout the range of the transmitter. Approximate settings for in-between frequencies can be obtained by interpolation.

In general, the antenna tuning system consists of a circuit whose purpose is to tune the antenna to resonance and a circuit whose purpose is to match the impedance of the antenna circuit to the power amplifier plate tank circuit so that a maximum transfer of power will take place. Because of the wide variety of antenna sizes used, it is impossible to list approximate dial settings except those for the so-called standard antenna.

Intermediate frequency transmitters use grounded quarter-wave antennas. Thus the greatest possible electrical length is obtained with the short antenna in use on board ships.

In general, the antenna should first be tuned to resonance while using low-power (low-plate voltage) and fairly loose coupling. When the antenna has been tuned to approximate resonance, as indicated by maximum antenna current, full-plate voltage can be applied.

At the lower intermediate frequencies the common shipboard antenna is capacitive, so a large variable inductance must be used in the transmitter to tune the antenna to resonance. This inductance is usually made up in two parts, a large tapped coil for rough adjustments and a variometer, or some other type of continuously variable inductance, for fine adjustment. Where the frequency range desired is very large, two complete circuits may be used for antenna tuning, a switching arrangement being used to switch from one circuit to the other. Tuning is simply a matter of adjusting the inductance until maximum antenna current is indicated. These adjustments should be made on low power and with rather loose coupling.

With full-plate voltage on the power amplifier the coupling should be adjusted until the tube draws normal, full power, plate current. If retuning the antenna causes plate current to rise above normal, it means that the coupling is too tight. The coupling should be decreased and the antenna retuned. At the final adjustment it should be possible to tune the antenna to both sides of resonance without the plate current rising above normal. Each change in antenna tuning or coupling should be followed by retuning the power amplifier tank circuit.

When the circuits are tuned and all adjustments are sharp, antenna current maximum, and plate current and voltage normal, it should be possible to lock the key without overheating the tube.

In a few types of transmitters a certain very definite technique is required. In such cases the prescribed tuning procedure should be followed carefully.

When an antenna is fed through a trunk the tuning technique remains the same. However, in this case, the antenna current read at the transmitter will not be the same as that at the base of the antenna proper.

HIGH FREQUENCY TRANSMITTERS

Trouble experienced in tuning HF transmitters is usually caused by insufficient knowledge of the transmitter circuits and the process of frequency doubling.

Frequency doubling is a process by which the plate tank circuit of an amplifier develops r. f. power at a frequency exactly twice that of the voltage driving the grid of the amplifier tube. The output of a class C amplifier is rich in harmonics. If the plate tank circuit is tuned to the second harmonic a heavy oscillating tank current will flow in the circuit and a considerable amount of power will be developed at this harmonic frequency. The voltage developed across the plate tank circuit may then be used to drive the grid of another amplifier tube. This process makes it possible to generate power at a low frequency, to multiply this frequency several times, and to radiate power from the antenna at a much higher frequency than that generated in the oscillator. This gives better frequency stability and higher efficiency in the main power amplifier.

When an amplifier plate tank circuit is tuned to the frequency of the grid excitation, it is then operating at the fundamental, or singling. When the tank is tuned to twice the grid-circuit frequency the circuit is doubling, and so on. To double efficiently the grid bias used with the amplifier must be very high. This allows the maximum plate current to flow at a time during the cycle when the plate voltage is low, as explained in connection with class C amplifiers.

The intermediate stages of many Navy transmitters are designed for operation either as FUNDAMENTAL amplifiers or as DOUBLERS. This makes it possible to obtain the wide frequency coverage required in these transmitters. The bias is fixed at a value which is a compromise between that which is best for singling and that which is best for doubling. Although some loss in power output and efficiency results this is not so important since these amplifiers are not required to furnish much power. Their main purpose is to make the desired frequency coverage possible and to furnish the small amount of power necessary to drive the main power amplifier.

The main power amplifier usually singles and is required to develop considerable power output at good efficiency. Its bias is therefore correct for this type of operation and if an attempt is made to double in its plate circuit the output will be low, tuning will be difficult, and the tube will overheat.

In some transmitters the adjustment for low power cuts the main power amplifier completely out of the circuit. The last intermediate amplifier is then required to act as a power amplifier and drive the antenna. You will generally find that operation of the last intermediate power amplifier as a doubler will cause tuning to be difficult and the tube to overheat. This condition is the result of insufficient bias for correct operation as a doubler due to the large increase in power input necessary to drive the antenna. This method of obtaining low-power operation curtails the frequency range to that over which the last intermediate amplifier can be operated as a fundamental amplifier. In many transmitters having a full-power range up to 18100 kc. this limits the low-power frequency range to 9050 kc.

Each stage in a transmitter is designed to cover a certain frequency range. The first stage may cover only the range from 4000 to 9050 kc., while the second stage and the main power amplifier will cover from 4,000 to 18100 kc. You should be familiar with the frequency range of each tuned circuit so that no doubt will exist as to whether the amplifier is singling or doubling.

It is standard practice to arrange all dials so that dial readings increase with frequency. They do NOT, as a rule, increase DIRECTLY with frequency.

Since the main power amplifier always singles, normally its dial reading will be approximately the same as that of the last intermediate amplifier when the transmitter is properly tuned.

The first dip in plate current found while proceeding from the lower end of the scale towards the upper end does not necessarily indicate that the amplifier is singling. The lowest frequency to which the circuit will tune may not be low enough to resonate at the excitation frequency.

Suppose your transmitter consists of an oscillator with a range of 2000 to 4525 kc., a first i. a. (intermediate amplifier) having a range of 4000 to 9050 kc., a second i. a. and main p. a. (power amplifier) both having a range of 4000 to 18100 kc. You wish to tune the antenna to 12000 kc.

The main p. a. and second i. a. will then be tuned to

12000 kc., the first i. a. will be tuned to 6000 kc., and the oscillator output frequency will be 3000 kc. The four circuits single, double, double and single respectively.

First, tune the oscillator to the correct frequency, 3000 kc., with the aid of the heterodyne frequency meter. The first i. a. CANNOT single at this frequency BECAUSE ITS TANK CIRCUIT WILL NOT REACH 3000 KC. Therefore, as you increase dial readings from the lower end of the scale you know that the first dip in plate current will indicate resonance at 6000 kc. and that you are doubling. The second i. a. will tune to any frequency within the range of the first i. a., so you pass over the first dip as you tune up for the lower end of the dial. The second dip indicates resonance at 12000 kc. You can bring the main power amplifier into approximate resonance while the key is up by setting its dial to approximately the same reading as that of the second i. a. dial, obtaining exact resonance with the key down by slight retuning. There should be only one resonance point obtainable in the main p. a. because it ordinarily will not reach 24000 kc.

When an attempt is made to double in the plate circuit of an amplifier which is not properly biased, the result will be very poor output and overheating of the tube. You can tell whether an amplifier is singling or doubling by first finding the frequency limits to which it can be tuned and then counting the resonant dips as the amplifier tuning is increased from the low frequency end of the scale. The method used to tune the amplifiers in any HF transmitter to any frequency within the range of the transmitter requires only a little knowledge about the transmitter.

The following points will aid you in tuning transmitters:

1. Tune slowly when making adjustments near the high-frequency end of the dial. One division on the dial may represent two or three times as many kilocycles at the upper end of the dial as at the lower end. The excellent circuits now in use make tuning very sharp.

2. Be sure you know the frequency range of the amplifier you are tuning and whether or not it will single.

3. The fundamental should cause a more pronounced dip in plate current than the second harmonic and the second harmonic a more pronounced dip than the third, etc. If slight dips are seen at odd points on the dial, determine the frequency at which they occur from the tuning curve. It will probably be an unwanted harmonic of some previous stage feeding through the amplifier.

As in the case of intermediate frequency transmitters, curves and tuning data for all the stages in the transmitter will be available in the instruction book. The transmitter is usually calibrated and tuning control settings posted for commonly used frequencies. Settings for other frequencies can be found by interpolation between these known settings. The information and methods given in preceding paragraphs can be used as an aid in calibrating the transmitter and in locating trouble caused by improper tuning.

CRYSTAL-CONTROLLED OSCILLATORS

Some transmitters use a crystal-controlled oscillator circuit. This type of oscillator circuit is becoming obsolete for shipboard use, except for very high frequencies. The main reason for this is the great number of crystals needed for the coverage of the Navy frequency band. The frequencies at which these transmitters can be used are limited to the fundamental and harmonic frequencies of the crystals on hand.

Quartz crystals used in oscillator circuits must be cut and ground to extremely accurate dimensions. A typical finished quartz crystal is shown in figure 121(2). The dimensions for a crystal resonant at 1000 kilocycles would be approximately 1 by 1 by 0.1125 inch. Electrical contact with the quartz crystal plate is made by a special holder, which has two metal plates (between which the crystal is mounted), and a spring device which places mechanical pressure on the metal plates. A dismantled holder of this type is shown in figure 121(1), and a view of a complete crystal and holder is shown in figure 121(3). Another type of crystal holder is shown in figure 121(4).

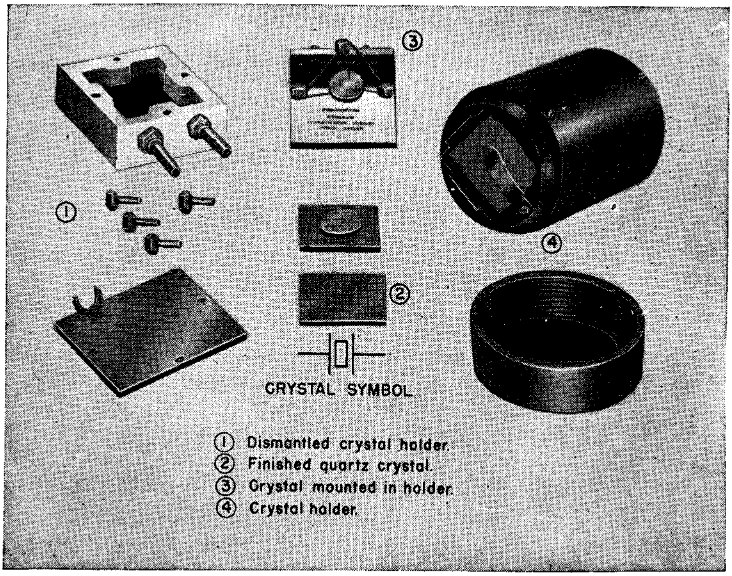


Figure 121.—Typical crystals and holders.

CRYSTAL OSCILLATOR CIRCUITS

CRYSTAL OSCILLATOR CIRCUITS are similar to the tuned-grid, tuned-plate circuits, except that the grid tank is replaced by the crystal circuit.

Figure 122 is a crystal oscillator circuit using a tetrode. The excitation voltage to keep the crystal oscillating comes from the feed-back produced by the interelectrode capacitance of the tube.

The first impulse that starts oscillation comes from the THERMAL AGITATION and SHOT EFFECT within the tube.

When the tube is turned on, some of the electrons pushing to the plate will strike against the grid. This gives the grid a NEGATIVE POTENTIAL which distorts the crystal slightly, setting it in vibration. As the crystal vibrates, it generates an a. c. voltage.

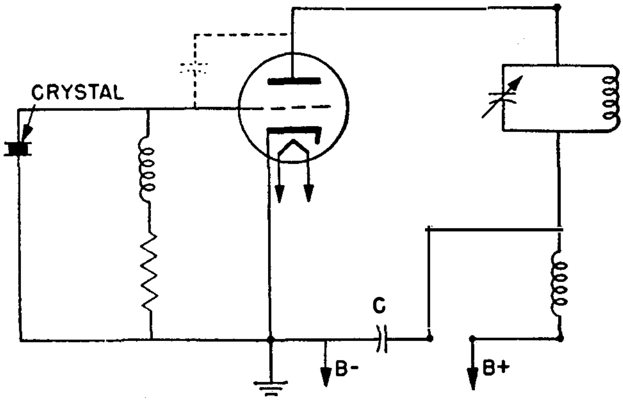


Figure 122.—Crystal oscillator circuit.

The potential generated by the crystal is placed on the grid, and is amplified in the plate circuit. Changes in the plate potential are reflected back to the grid circuit, providing a continuous electrical stress to keep the crystal oscillating.

The two plates of the crystal holder form a CONDENSER, which conducts an r. f. current. If this current becomes too large, the crystal may BURN or CRACK. To prevent this, the power output of a crystal oscillator is limited.

TUNING CRYSTAL-CONTROLLED TRANSMITTERS

Tuning the intermediate amplifier and main power amplifier stages of crystal-controlled transmitters is performed as outlined under high frequency transmitters.

To facilitate crystal oscillation it is necessary for the plate tank circuit of the crystal stage to be tuned, so that it is inductive at the crystal frequency. Therefore, the resonant frequency of the plate circuit must always be higher than the crystal frequency.

If tuning is begun with the plate tank circuit tuned to a frequency higher than the crystal frequency, and the dial turned slowly towards a low frequency, you will find that the crystal will break into oscillation, indicated by a sudden rise in crystal r. f. current. The crystal current will continue to rise to a peak as the plate tank is brought into resonance and will drop to zero as resonance is passed. Operation of the circuit at the crystal current peak results in very unstable oscillation, since small changes in the tuned circuits will cause the circuit to *slop* over, become capacitive, and stop oscillating.

If curves are made of crystal current, grid current in the first i. a., and oscillator plate current drawn against plate tank circuit resonant frequency, you will see that the grid current peak is always reached before the peak crystal current or oscillator plate peak is reached. Furthermore, you'll note that very stable operation can be obtained by operating at the point where grid current in the following stage is highest. Crystal current and plate current are lower at this point. Consequently the tube and crystal heat less and the frequency of oscillation therefore has less tendency to creep.

CARE AND CLEANING

In the *ET* 2 manual training course, NavPers 10143–A, you studied crystal oscillators. The crystals used for the control of frequency sometimes behave rather temperamentally. Frequently the crystal, for no apparent reason, will stop oscillating and you'll have considerable difficulty starting it again. Occasionally, this can be overcome temporarily by tapping the crystal holder lightly. However, when a crystal starts to behave erratically, it is usually a sign that moisture or oil has fouled the surface of the crystal, or that the metal electrodes have become deranged. It is then necessary to remove the crystal from its holder for cleaning.

Pure grain alcohol is the best cleaning agent. The use of soap and water is discouraged because it is practically impossible to remove all traces of soap and moisture from the crystal. Carbon tetrachloride is a good cleaning agent, providing it hasn't been colored.

Care must be exercised when removing the crystal from its holder so as not to chip or crack the crystal. The crystal should be given a good bath in alcohol to remove all traces of dirt, oil, or moisture. It must not come in contact with the bare hands because a deposit of body oil or dirt may form on the crystal.

The electrodes inside the holder are also cleaned with alcohol. A clean linen handkerchief free from all lint can be used to dry the crystal and holder parts. Great care must be taken that no traces of lint or other foreign matter remains on the surfaces of the crystal or inside the holder. The holder and crystal may then be reassembled, firmly sealing the crystal against dust or moisture.

ELECTRON-COUPLED OSCILLATOR

One of the commonest types of oscillators you will work with is the ELECTRON-COUPLED OSCILLATOR. The only connecting link between the GRID and the PLATE circuits is the stream of ELECTRONS through the tube, hence its name.

The electron-coupled oscillator in figure 123 uses a TETRODE, although it is also possible to use PENTODES. The screen grid isolates the plate and control grid, thus reducing the interelectrode capacitance of the tube.

The cathode, control grid, and screen grid form a Hartley oscillator circuit with the screen grid acting as the plate. Feed-back takes place between the screen and control grid. The frequency of oscillations is controlled by L_1 and C_1 in the grid tank circuit. The oscillator section of the circuit operates as a separate and independent unit. Oscillations will continue without interruption even if the plate is disconnected.

The extremely good frequency stability of these oscillators comes from taking advantage of every possible circuit refinement. These include: Temperature control of the tuned circuits; obtaining screen and plate voltages from a common source to take advantage of the

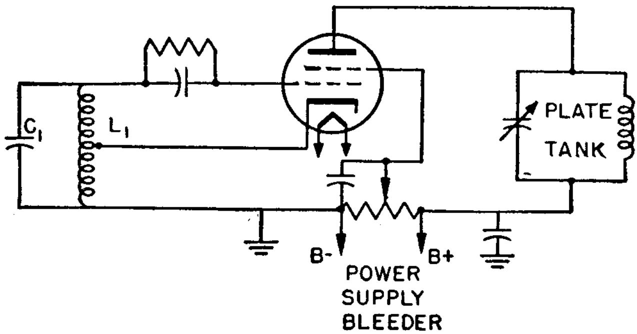


Figure 123.—The electron-coupled oscillator.

compensating effect secured when the supply voltage varies; and reducing plate-to-grid reaction through the tube capacities to a negligible amount BY ALWAYS TUNING THE PLATE TANK CIRCUIT TO TWICE THE OSCILLATION FREQUENCY.

The plate tank circuit has constants such that its over-all frequency range is slightly more than twice that of the oscillator portion of the circuit. Although this circuit should always be tuned to twice the oscillator frequency there is nothing automatic about it. It is possible to single or double at one end of the oscillator frequency range or to double or triple at the other end. The tuning curves for the oscillator and doubler (the plate tuned circuit) are usually marked with the same frequency ranges and no indication is shown that the oscillator is operating at half the frequency of the doubler circuit. If these curves are carefully followed, tuning of the doubler will always be correct.

Difficulty in tuning the doubler is usually caused by attempting to tune the circuit without reference to the curves and at the same time not realizing the fact that doubling is not automatic. The circuit can best be adjusted by tuning for maximum plate current in the first intermediate amplifier. When this is done hurriedly there is a chance you will tune to the fundamental frequency of the oscillator or to its third harmonic, depending upon which end of the oscillator frequency range is being used.

Mistuning can be prevented by learning the frequency range of the doubler. If this range is from 2000 to 4525, it is logical to believe that 2500 kc. will lie near the lower end of the scale, 4000 kc. near the upper end, and 3000 kc. near the center.

When putting an electron-coupled oscillator and doubler circuit on frequency with a heterodyne frequency meter you may have difficulty hearing the beat note if the frequency meter is tuned to the frequency desired and the doubler is very far out of resonance. This can easily be overcome by setting the frequency meter for the frequency actually desired in the OSCILLATOR portion of the circuit. Thus, if 3000 kc. is desired as the output frequency of the doubler, the frequency meter would be tuned to 1500 kc., the frequency at which oscillations will be generated.

If you want to tune the doubler to resonance while the TUNE-OPERATE switch is still in the TUNE position it can be done by determining the approximate setting. Next, tune for the small, rather obscure dip in OSCILLATOR plate current which occurs when the doubler is tuned through resonance.

This method is preferable to tuning for maximum plate current in the following stage since less change in oscillator frequency occurs when the doubler is tuned in this manner.

HF TRANSMITTER ANTENNA CIRCUITS

The ordinary high frequency transmitter antenna tuning unit is designed to tune a typical shipboard antenna to resonance at any frequency within the range of the transmitter. Because of the widely varying frequency

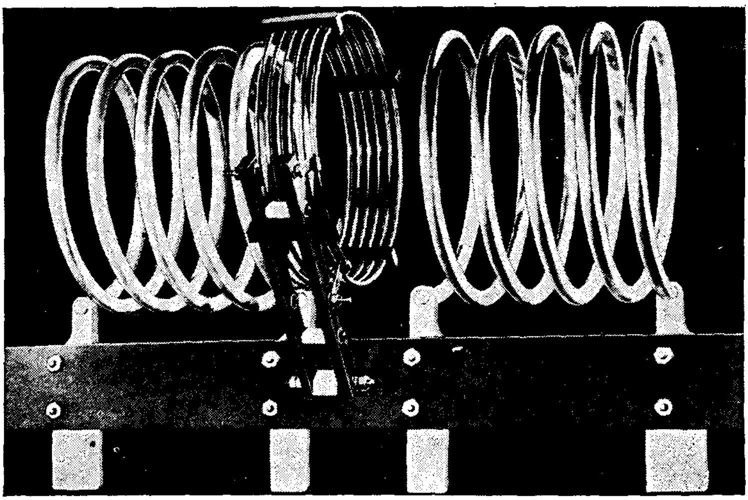


Figure 124.—Transmitter coupling coils.

characteristics of shipboard antennas, and because these antennas are frequently tuned through trunks, it is almost imposible to lay down a method of tuning that will hold strictly true under all conditions. Only in rare cases will the antenna actually be resonant at the desired frequency. Unless it is resonant, you'll have to tune it to resonance by lumped inductance and capacity at the base, or transmitter, end.

The antenna tuning system is made up of a continuously variable coil and condenser which may be connected either in series or parallel. One side of the combination is usually grounded through a switch which is part of the tuning system, and the other side is connected to the antenna. A coupling condenser is usually connected into the system between the coil and condenser and to the power amplifier plate tank circuit.

Whatever frequency you want, the point at which the antenna connects to the antenna tuning unit will have an impedance determined by its electrical length at that frequency. If the frequency causes the antenna to have a VOLTAGE loop close to this point, you are feeding power in at a point of high impedance, and should use voltage feed. If a CURRENT loop is close to this point, you are feeding at a point of low impedance and the antenna should be current-fed.

Regardless of whether the antenna current motor is connected on the ground or antenna side of the antenna tuning system it reads ONLY THE CURRENT AT THE POINT WHERE IT IS CONNECTED. The antenna should be tuned to resonance by adjusting the circuit for maximum antenna current but the value obtained will, in general, be different for every frequency.

Whether or not voltage or current feed should be used for any particular frequency can only be determined by experiment. Normally, the method of feed which produces the best over-all results is the proper one to use.

Once the antenna has been tuned to approximate resonance you'll notice that power amplifier plate current will begin to rise. This tells you that the power is being transferred to the antenna.

The power amplifier plate circuit should now be retuned to resonance as indicated by a dip plate current. In fact, with every change in antenna tuning or coupling you should follow by retuning the power amplifier plate circuit.

Readjustment of the antenna circuit may cause the power amplifier plate current to continue rising until the rated maximum plate current has been reached. But a condition then exists which indicates that further retuning of the antenna circuit could make the plate current rise higher.

This brings the coupling condenser into the picture. Its purpose is to help you match the impedance of the antenna circuit to the impedance of the power amplifier plate tank circuit at the point where the coupling condenser is connected. It performs much like a voltage divider in that by changing its reactance at the resonant frequency the voltage across it changes. As a result, the proportion of plate tank circuit voltage actually applied to the antenna tuning circuit is changed. Decreasing the capacity of the coupling condenser increases its reactance and therefore the voltage across it. When the voltage across it is high, the voltage across the antenna tuning circuit will be low. Less power is transferred from the tank to the antenna and the coupling is said to be loose.

You have a condition where maximum plate current was reached before the antenna was exactly tuned to resonance. The coupling should now be loosened and the circuits retuned. By repeating this process a condition will be reached where the antenna can be exactly tuned to resonance and the power amplifier circuit also tuned to resonance. The power amplifier plate current can be brought to its maximum value by the use of the coupling condenser. Further retuning of the antenna circuit will not cause an increase in either the plate current or antenna current. UNDER THIS CONDITION THE TUNING OF THE POWER AMPLIFIER PLATE CIRCUIT WILL BE SHARP AND POSITIVE, AND THE KEY CAN BE HELD DOWN INDEFINITELY WITHOUT CAUSING THE TUBES TO OVERHEAT. THESE CONDITIONS ALWAYS INDICATE PROPER TUNING. At some frequencies very close coupling is required while other frequencies require loose coupling. When shifting frequencies remember that the proper coupling point may be near the opposite end of the scale from that at which the antenna was just adjusted. This condition is indicated when, for instance, adjusting the condenser to what should be a looser coupling adjustment actually causes plate current to increase. This simply means that the antenna is OVERCOUPLED at the new frequency. Continued loosening of the coupling will reveal a peak beyond which plate current gain falls off.

Do not be alarmed if antenna tuning for the same frequency seems to change somewhat from day to day. This simply means that the characteristics of the antenna have changed slightly due, possibly, to shifting of large masses of material near or under the antenna, such as planes, cranes, boats, etc. Or the change may be due to wetting down decks, or radical changes in humidity which cause moisture to collect in the field of the antenna. These things all affect the electrical characteristics of the antenna and change the tuning of the antenna tuning system.

POWER SUPPLIES

When high voltage direct current is required for use in radio gear, it is usually obtained by the following methods: (a) By transforming a low a. c. voltage to a high d. c. voltage by transformer, rectifier, and filter action; (b) by transforming a low d. c. voltage to a high d. c. voltage by a voltage vibrator, transformer, rectifier and filter action; and (c) by converting a low a. c. or d. c. voltage to a high d. c. voltage by use of rotating machinery such as motor generators or synchronous converters.

POWER TRANSFORMERS

Fundamentally the theory and operation of power transformers used with rectifier power systems do not differ from any other power transformers. There are, nevertheless, certain points which apply to a rectifier transformer which must be discussed. These points are:

heating, d. c. saturation, utilization factor, auxiliary windings and electrostatic shielding.

Heating in a transformer used for rectifier service is more pronounced for a given power than if the same transformer were used in a conventional circuit delivering power to a resistance load. This is due to the irregular shaped current waves drawn by the rectifier, producing more heat than if delivering pure sine waves.

Direct current saturation due to the pulses of direct current flowing in the secondary tends to reduce the number of lines of force or flux. As a transformer depends for its operation on the number of lines of force, any reduction in these lines will reduce the effect of transformer action. This loss can be compensated for by the insertion of an air gap a few hundredths of an inch in the magnetic path of the core.

The utilization factor of a power transformer used in rectifier circuits is the ratio of d. c. power output to the normal a. c. rating for the same transformer copper losses and depends upon the rectifier connections.

The number of windings and particular construction of each depend entirely on the service to which the transformer is to be put. Practically all transformers used in receiver power supplies have auxiliary windings to supply filament power to various tubes. All auxiliary windings operate in conjunction with the high voltage winding from a single primary. In transformers intended for use with high power transmitter systems, it is necessary to employ separate transformers for auxiliary purposes.

Another very important point in transformer design is electrostatic shielding. This shield may be in the form of an auxiliary winding placed between the primary and secondary and in turn grounded. This ground is usually to the transformer case and an external ground. Use of center-tapped filament or heater windings may be used if they are placed between the primary and high voltage secondary.

Another method quite commonly used is the reversed winding method. This consists of using the normal outside connections as the center tap ground and utilizing the broken center tap as the normal lead connections. The function of the electrostatic shield is to prevent disturbances in the power line from reaching tube circuits and transient high frequency oscillations from the equipment from feeding back into the power line. The use of line filters in the power circuit to the transformer is also an aid in suppressing troublesome feedback.

The rating of power transformers normally specifies the input voltage and frequency, the secondary output volts, current, and power. It is common practice to rate general power transformers according to their safe output in kilovoltamperes.

RECTIFIERS

In radio transmission and reception, vacuum tubes are employed for the generation, detection, and amplification of radio frequency currents. In addition, electron tubes serve as power rectifiers which convert alternating current into direct current and in special cases for controlling and inverting electric power.

You should understand that the purpose of any rectifying device is to convert or change alternating current into a pulsating direct current. Because electron tubes are one of the most important types of rectifying devices, a thorough understanding of the action of the tube itself is necessary. (See ch. 4.)

PLATE AND SCREEN POWER SUPPLY CIRCUITS

Power for the plates and screens of a transmitter can be supplied by either a motor-generator set or by a rectifier system. Transmitters use tetrodes or pentode tubes as intermediate power amplifiers and tetrodes or triode tubes as main power amplifiers. The tetrodes and pentode tubes require high d. c. plate supply voltage and somewhat lower voltages for the screens. It is common practice to obtain both of these voltages from the same power source. Oscillator tube power is usually supplied from a separate armature or rectifier to insure frequency stability.

A typical transmitter which uses a motor generator for a power supply has two high voltage armatures. One supplies the oscillator with plate and screen voltage and has an output voltage of 1,000 volts. The other armature is double-ended, one commutator supplying 2,000 volts and the other 1,000 volts. Across the 2,000-volt armature is a voltage divided which supplies the proper voltages to the screen grids. Approximately 2,000 volts is supplied to the plates of the intermediate amplifier tubes. The power amplifier tube receives its screen voltage from the 2,000-volt divider but the plate potential is raised to approximately 3,000 volts by connecting the two commutators of the high voltage generator in series. A TUNE-OPERATE switch provides reduced voltages for tuning by connecting the plate of the main power amplifier tube to the 2,000-volt terminal and by connecting a voltage-dropping resistor in series with the plate circuits of the intermediate amplifier tubes.

Each individual plate circuit contains an r. f. choke which keeps r. f. currents from flowing into the power-supply system. In addition the circuits are suitably by-passed by large condensers.

When a rectifier power supply is used the full output voltage of the main plate rectifier is applied to the plate of the main power amplifier tube. Lower voltages for the intermediate power amplifier plates are obtained from a neutral tap on the rectifier. The voltage supplied by the neutral connection is about 50 percent of the main rectified plate voltage. A voltage divider connected across the neutral and ground (negative) terminals, in the transmitter unit, provides the proper screen voltage. The oscillator circuit is supplied with plate and screen power from a separate, full-wave rectifier. All high voltage circuits are bypassed to ground by suitable condensers. Each high-voltage armature is always fused, and the fuses are generally placed in the terminal box mounted on the generator frame. In series with the negative high-voltage lead will usually be found the coil of the plate overload relay.

BIASING

BIASING SYSTEMS for transmitters may use either POWER-SUPPLY BIASING, GRID-LEAK BIASING, OR CATHODE SELF-BIASING.

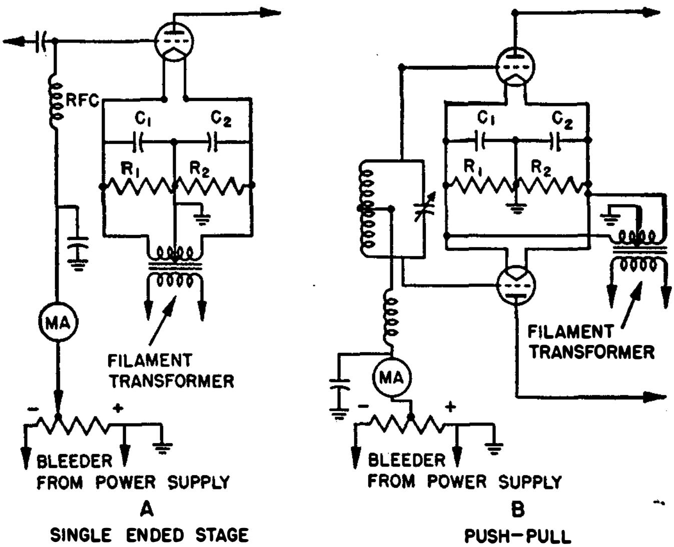


Figure 125.—Power-supply biasing systems.

However, with either of the first two systems, you'll need to use some sort of PROTECTIVE SYSTEM to keep the tube from being overloaded and destroyed in case the bias supply fails. You'll find that this protective system usually consists of CATHODE BIAS in combination with either power-supply or grid-leak biasing. Some transmitters are equipped with overload relays to protect the tubes. Overloads open these relays and prevent excess plate currents.

The two circuits in figure 125 show power-supply biasing that can be used with either single-ended or push-pull tubes. The bias voltages are obtained from a special BIASING POWER SUPPLY. Notice that the POSITIVE terminal of the bleeder resistor is grounded.

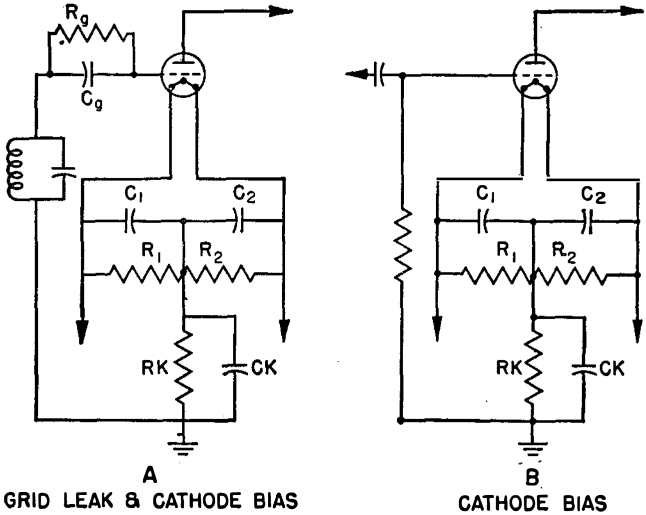


Figure 126.—Biasing systems used in transmitter circuits.

This method is used with class C amplifiers as well as with class B. The milliammeter (ma) between the grid and the bleeder shows the current flowing.

Resistor R_1 and R_2 in combination with condenser C_1 and C_2 form a filter to reduce the a. c. line hum. They are used with the center tap secondary of filament transformer, and are used wherever directly heated cathodes are used.

Figure 126a is a combination of grid-leak and cathode biasing. Resistor RK and condenser *CK* are the usual cathode resistor and bypass condenser. Approximately half the bias is developed by the grid-leak and the other half is developed by the cathode system.

The system illustrated by figure 126b is seldom used because it is difficult to operate it better than class AB_2. The chief purpose of the r. c. filter bridge in the cathode circuit is to bypass as much of the power-line a. c. hum as possible to ground.

FILAMENT POWER SUPPLY CIRCUITS

Filaments of transmitting tubes are usually operated from transformers. The principal differences in design of the circuits are in the transformers themselves.

The typical transformer has a separate secondary winding for the oscillator tube filament, a winding which supplies all intermediate amplifier filaments if the tubes use the same filament voltages and a third secondary winding which supplies the filament of the main power amplifier tube.

Design of the transmitter usually requires that the filament of the oscillator tube be operated from a separate secondary winding and in some cases from a separate transformer. This simplifies the design of the keying and biasing circuits and prevents varying power and intermediate amplifier plate currents, which must flow through the secondary windings to the filaments, from affecting the oscillator filament voltage and possibly its output frequency.

It is more convenient, and cheaper, to design separate secondary windings for power amplifier tubes which require different filament voltages than it is to use one winding and to depend on filament rheostats or series dropping resistors to reduce the voltage to a value suitable for the smaller tubes.

The design of these transformers depends on whether the transformer is supplied from an a. c. power line at the common frequency, 60 cycles, and the common voltages, 110 and 220 volts, or whether it is supplied with power from collector rings on a motor.

If power is taken from collector rings on a motor, the frequency will depend on the motor speed and the number of poles in the machine. The voltage taken from the rings will be about 71 percent of the d. c. line voltage. The voltage developed at the slip rings is actually the counter e. m. f. of the motor. It is sinusoidal (sine-wave) in character and has an effective value equal (approximately) to 0.707 times the line voltage.

If a rectifier power supply is used, the primaries will be designed for 110 and 220 volts. They may or may not be supplied direct from the power line.

When a transmitter is designed so that switching to LOW POWER disconnects the main power amplifier tube, the switch usually connects a DUMMY resistor into the filament circuit. The dummy resistor takes the place of the power amplifier tube filament, keeping the load on the transformer constant. This makes it unnecessary to readjust the filament voltage.

Stand-by operation of the oscillator filament is often provided. A switch causes a relay to shift the oscillator filament from the regular running transformer to an auxiliary transformer; or it may connect the primary of the separate oscillator filament transformer directly to terminals in the transmitter where the proper voltage is available when the rest of the transmitter is shut down. Stand-by operation keeps the filament of the oscillator tube at a constant temperature and allows the various parts of the tube, and the devices close to it, to reach and maintain their normal operating temperature. This in turn lessens the chances of frequency drift due to changing temperatures in and around the tube.

Rectifier tubes can be operated in the stand-by condition. The switch that provides this operation may simply short-circuit the contacts of the filament starting relay, thereby maintaining the circuit from the filament transformer primaries to the line. The purpose of using stand-by operation of rectifier filaments is to eliminate the 30-second wait before rectifier plate voltage can be applied. It is especially useful when the set is to be continually started and stopped.

The filaments of rectifier tubes which are operated in single phase, full wave, rectifier systems are ordinarily operated in parallel. Design of these transformers calls for very good insulation between primary and secondary, and to ground, since the full inverse peak voltage is between the primary and secondary windings.

The transformer requirements of three-phase rectifier filament systems depend on the type of system used—half wave or full wave—and on the power to be handled. These systems usually employ six rectifier tubes. If the system is designed for half-wave rectification the filaments may be connected in parallel across one transformer secondary. However, the effects of load current flowing in the transformer secondary may easily affect the filament voltage. When the amount of load current is likely to cause this effect, separate filament transformers are used.

When a three-phase, full-wave, rectifier circuit is used there must be at least four separate filament transformers for the six rectifier tubes. One of these transformers supplies three tubes which have their filaments connected in parallel while each of the remaining tubes has its own separate filament winding. In this type of system use of less than four transformer windings would short-circuit one or more tubes because two tubes must be connected in series across each phase.

When mercury vapor tubes are used in these rectifier systems, means are provided for burning the filaments for a definite length of time (15 to 30 minutes for new tubes; 30 seconds or more for tubes already in service) before application of plate voltage. This insures that any mercury deposited on the filament or plate is evaporated. Otherwise, there is a risk of flashback which would ruin the tube.

Transmitters are often designed for operation from two different line voltages. In that case provision is made for the use of different voltages on the primaries of the filament transformers. Usually two voltages are provided for: 115 and 230 volts direct current; or 110 and 220 volts alternating current. The primaries are then wound in two sections with all the terminals brought out and numbered. For 115-volt direct current and 110-volt alternating current operation the two sections are connected in parallel and for the higher line voltages the two sections are connected in series. This system is often used in the construction of other types of transformers.

CONSTANT TEMPERATURE COMPARTMENTS

Constant temperature compartments are a necessary part of all high-frequency transmitters. The crystals in crystal-controlled transmitters require a constant temperature to prevent frequency drift. The frequency determining portions of electron-coupled oscillator circuits, commonly used to control the frequency of HF transmitters, must be maintained at a constant temperature for the same reason.

Temperature is held practically constant inside the compartment by means of a thermostat and an electric heating element. The thermostat acts as a switch, connecting the heating element to the line when the temperature drops below a certain predetermined value. It disconnects the heating element when the temperature rises above this value.

Obviously you can't take the term CONSTANT TEMPERATURE too literally since it is impossible to maintain an absolutely constant temperature. In fact, the thermostat's operation depends on changes in temperature.

Since the thermostat's operation depends on CHANGES in temperature it is necessary to hold the compartment temperature well above that of the surrounding air. The upper ambient temperature limit at which these boxes are required to operate is 50° C. and the lower limit 0° C. Therefore, most compartments are designed to hold the temperature of the box at 60° C. However, many crystal ovens in use today operate at 50° C. Check your instruction for further information.

REMOTE CONTROL CIRCUITS

Most transmitters in use at present are equipped for operation with the standard four-wire remote control unit. This unit has a hand key, a start-stop switch of the toggle type, and a pilot light, all mounted on a small bakelite panel.

The circuits of the four-wire remote control unit and typical transmitter circuits used with it are shown in figure 127.

All circuits use the common negative connection. The key completes the keying relay circuit to the negative side of the line. The switch connects the master relay across the line while the pilot light is across the coil of the master relay and is energized when the start-stop switch is closed.

In general, transmitters built for shipboard use must meet the following requirements in their keying and start-stop circuits:

1. Provide a local-remote switch that, when in local position, will cause the remote control circuits to be inoperative and when in remote position will permit control from the remote control unit and from the front panel of the transmitter unit itself.

2. Provide an EMERGENCY shut-down feature which, when the equipment is stopped by use of the emergency switch, does not permit it to be started until the emergency switch has been placed in the ON position.

3. Provide terminals on the transmitter for connection to six- or four-wire remote-control units. Provide terminals on the terminal board for link connections required in changing from six- to four-wire control circuit operation.

4. Arrange transmitter circuits to facilitate the interchangeability of the start-stop switches so that the desired type of remote control circuit may be selected and the transmitter modified at the point of installation. The two-button momentary contact switch shall be installed and a suitable adapter plate furnished for installation of the maintaining toggle switch.

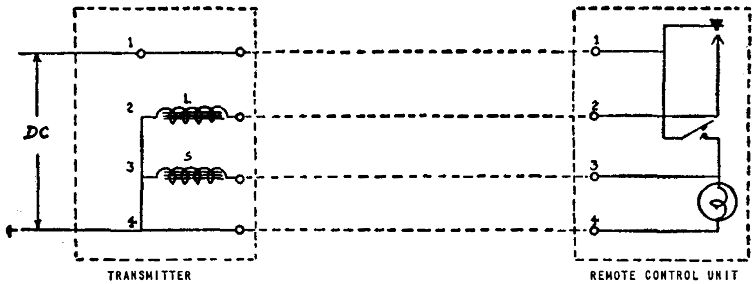


Figure 127.—Standard four-wire control circuit.

5. Use a standard potential of 110/115 volts direct current, for keying circuits. For a. c. supply equipments (four- and six-wire control circuits) and d. c. supply equipments (six-wire control circuits) obtain keying potential from the line; using suitable potentiometer to obtain standard potential from a 230-volt supply.

6. Use a standard potential of 110/115 volts alternating current for starting and indicator circuits in a. c. supply equipments. The line potential shall be used for starting and indicator circuits in d. c. equipment.

7. The keying potential shall not be available until the motor-generator has reached full speed.

SIX-WIRE CIRCUITS, A. C. AND D. C.

Supplementary requirements:

1. Equipment may be started and stopped locally by a two-button momentary contact, normally open switch. This feature to be operative when the local-remote switch is in the local or remote position.

2. Equipment may be started, stopped, and keyed from any connected remote control unit after the local-remote switch is placed in remote position.

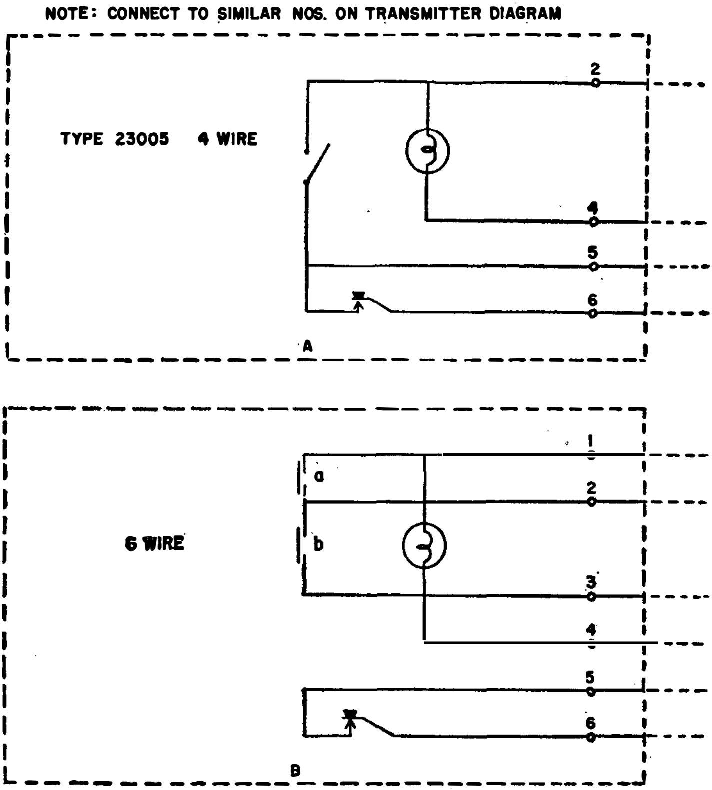


Figure 128.—Four- and six-wire remote control circuits.

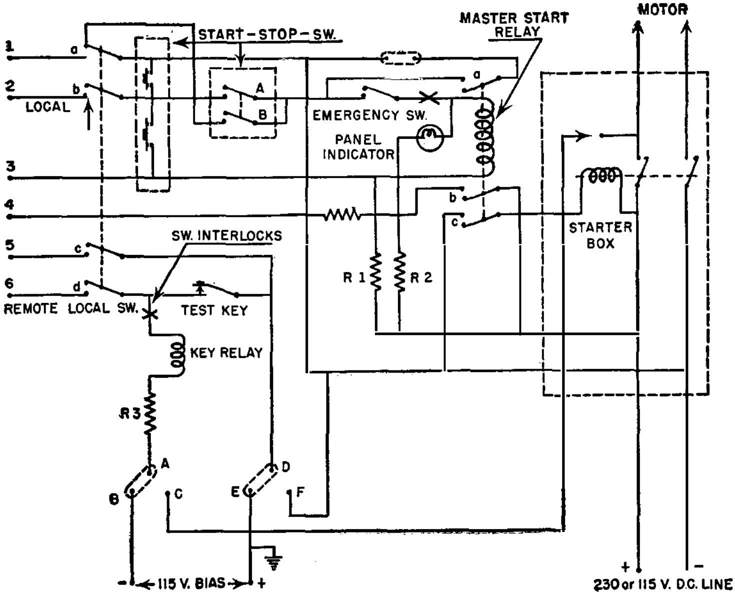


Figure 129.—Control circuits for four- or six-wire remote control units d. c. supply.

FOUR-WIRE CIRCUITS, A. C. AND D. C.

Supplementary requirements:

1. Equipment may be started or stopped locally by a contact toggle switch, this feature to be operative when the local-remote switch is in the local position. The equipment may be stopped locally when the local-remote switch is in the remote position or started locally if the remote starting switch is in the ON position, and the local-remote switch is placed in the remote position.

2. Equipment may be started, stopped, and keyed from a remote unit after the local-remote switch is placed in the remote position, and the local-start switch is placed in the start position.

3. Local indicator lamp connected in parallel with the master start relay.

4. Remote indicator lamp connected in parallel with the local indicator after local-remote switch is placed in remote position.

The circuits and terminal markings of the four- and six-wire remote control units are shown in figure 128a and figure 128b respectively. A schematic diagram of the internal transmitter circuits for d. c. operation from either of these units is shown in figure 129. The diagram of these circuits for a. c. operation is shown in figure 129.

These circuits meet all the requirements and are therefore more or less standard. However, you can expect some variations in different model transmitters and in transmitters built by different manufacturers.

TRANSMITTER CONTROL CIRCUITS

When four-wire control is used, starting and stopping must be done by the DPDT toggle switch with the transmitter LOCAL-REMOTE position on LOCAL. When control is on REMOTE starting and stopping is performed by means of a SPST switch connected between terminals 2 and 5. Figure 129 shows the REMOTE-LOCAL switch in position for LOCAL control operations.

Operation of the circuit is as follows: (a) REMOTE-LOCAL switch on REMOTE. (b) Transmitter START-STOP switch closed. (c) EMERGENCY switch and door interlocks closed. The circuit is from the 230-volt line through the voltage dropping and protective resistor and the coil of the master relay, through the door interlocks, the emergency switch, contact (a) of the DPST switch to terminal No. 2 on transmitter to terminal No. 2 in the remote control unit; from terminal No. 2 in the remote control unit through the SPST starting switch to terminal No. 5 in the remote control unit, to terminal No. 5 in the transmitter; from terminal No. 5 through the REMOTE-LOCAL switch through the link *D–F* to the negative side of the 230-volt line.

The master starting relay in the transmitter closes its contacts, completing a circuit from the 230-volt side of the line through the starting relay in the starting box, through contact (c) of the master relay back to the negative side of the line.

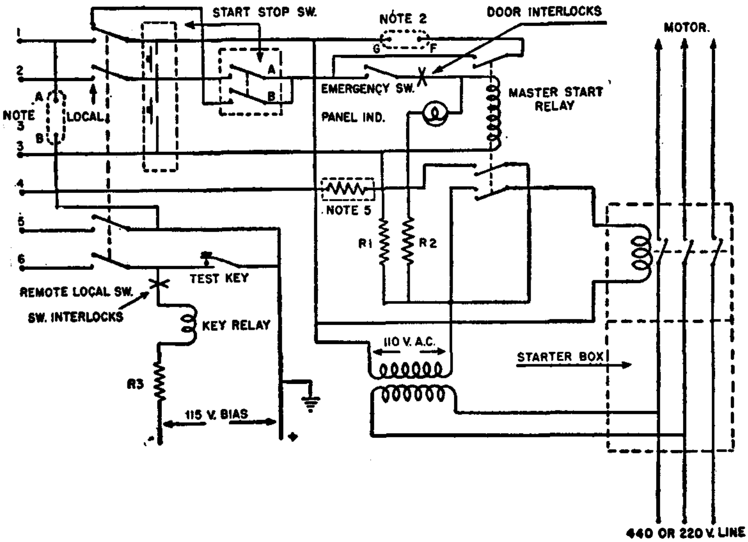


Figure 130.—Control circuits for four- or six-wire control units a. c. supply.

Another contact, (b), on the master relay, completes a circuit placing the indicator lamp in the remote control unit across the line through terminals No. 4 and No. 5, the remote-starting switch, contact (c) of REMOTE-LOCAL switch and link *D–F*.

When the motor-starter starting relay operates, it closes auxiliary contacts which form a circuit from the +230-volt side of the line. The keying circuit is not energized until the motor starter operates. The auxiliary starter contact should not close until the motor is up to speed.

Test-key operation of the keying relay is obtained through the circuit from the positive side of the line, through the auxiliary starter contact, through link *A–C*, the keying relay voltage-dropping resistor and coil, the switch interlocks, through the test key to the negative side of the line through link *D–F*.

SIX-WIRE CONTROL

To follow the explanation of six-wire control, refer to figures 128b and 129. When six-wire control is to be used, link *G* and *F*, *A* and *B*, *D* and *E*, replace DPST toggle switch with two-button momentary contact switch, and replace contact (a) of the toggle switch with a jumper. The keying relay circuit is thus shifted to the bias generator and is independent of the starting circuit.

Operation of the circuit is as follows: (a) Emergency and door interlock switches closed; (b) REMOTE-LOCAL switch on REMOTE; (c) depress starting button connected across terminals No. 1 and No. 2 in remote control unit.

The master relay is energized through the circuit from the positive side of the line through the voltage-dropping and protective resistor, master relay coil, door interlocks and emergency switches; then to the jumper across (a) of toggle switch connection, REMOTE-LOCAL contact (b) to terminal No. 2 in transmitter and in the remote control unit, through momentary starting button to terminal No. 1 in remote control unit to terminal No. 1 in the transmitter; thence through contact (a) of REMOTE-LOCAL switch directly to the negative side of the line.

The master relay is sealed to the line through the circuit from the positive side of the line, the relay coil and its protective resistor, the emergency and door interlocks, master relay contact (a) link *G–F* to the negative side of the line.

The remote control unit pilot light is energized through the circuit from the positive side of the line, through master relay contact (b), terminals No. 4 in the transmitter and remote control unit, through the pilot light back to terminals No. 1 in both the units; thence through REMOTE-LOCAL contact (a) to the negative side of the line.

The keying relay circuit will be energized when the bias generator is up to normal speed. Its circuit starts at the positive terminal of the bias generator, through link *D–E*, remote-local switch contacts (c) and (d) and the remote hand key via terminals No. 5 and No. 6 in both units, through the switch interlocks, keying relay coil, the voltage-dropping resistor, link *A–B* to the negative terminal of the bias generator.

To stop the motor generator, momentary contact button (b) is closed. This short-circuits terminals No. 2 and No. 3 and the master relay coil. The resistor R_1 prevents the short-circuit current from rising too high. Shorting the relay coil deenergizes it, its contacts open, the motor-starting relay is deenergized and the motor stops.

Alternating current operation of these circuits is almost the same as the operation of direct current. A standard voltage of 110 volts is used for the starting circuits and is provided by a separate transformer whose primary is across one phase of the three-phase line. The motor-starter relay has three sets of contacts which connect the a. c. motor to the three phases of the line. Keying relay voltage is provided by the bias generator for both four- and six-wire control. Changes necessary for switching from four- to six-wire control are shown in the diagram, figure 130.

The operation of these circuits for both four- and six-wire control should be worked out by the radioman for his own information and for practice.

POWER-CONTROL CIRCUITS

Transmitter power-control circuits provide for the proper application of the various voltages necessary to operate a transmitter. They also provide for protection against damage to apparatus and protection of operating personnel against fatal shock.

To function properly it is necessary that the circuits be rather complex, and closely interlocked, and are therefore, difficult to trace out and service.

Efficient servicing of these circuits can only be done after careful study of their arrangement in the transmitters.

The requirements which the circuits must meet are more or less the same in all Navy transmitters but different designers meet these requirements in different ways.

SAFETY OR DOOR INTERLOCKS

The purpose of interlocks is to prevent personnel from gaining access to the compartments in a transmitter, through the doors, without first removing all dangerous voltages from the transmitter circuits. Interlocks shut down the motor-generator set, where this type of power supply is used, or open circuits which remove voltage from all but the control circuit rectifier when a rectifier power supply is used. Filament circuits are opened in both cases.

When a motor generator is used the machine must be stopped. If the field circuits and filament primary circuits only were opened there would still be enough voltage present to cause severe shock. This voltage would be generated by the action of the residual magnetism in the field poles.

The door interlocks are switches, closed when the doors are closed. They are all connected in series with each other and in series with the coil of the master relay.

Door interlock switches installed in rectifier units are of the same type and usually operate to remove voltage from the main contacts during the time the main contacts are passing from one circuit to another. The voltage must be removed from these contacts to prevent burning and pitting. The main switch contacts may be in either r. f. or power circuits.

When the main switch is in an r. f. circuit and must break r. f. current the switch interlock usually removes the r. f. voltage by opening the keying relay circuit. When so used, the switch interlock contact is connected in series with the coil of the keying relay. All r. f. switch interlocks are connected in series. Opening any one of the protected switches causes the keying relay to open BEFORE the protected switch contacts open. Thus, pitting and burning is prevented. In fact, manufacturers found that it was cheaper to install switch interlocks than to develop a metal which would meet specifications regarding damage due to breaking heavy currents.

OVERLOAD RELAY CIRCUITS

A transmitter must have protection against two types of overload. The type most frequently met is the heavy surge of current which must be broken instantly to prevent damage to tubes, generators, or other pieces of apparatus. Protection against overloads of this kind is obtained by quick-acting relays whose contacts operate to open the circuits in which the overload occurs. These relays are usually magnetically operated.

The second type of overload is one which is not usually as heavy as the first type, will not cause immediate damage, but, if maintained over a period of time, will cause the generator, transformer, or some other piece of equipment to burn out. Protection against this sort of overload requires use of fuses, bimetallic relays and other types of slow acting cut-out devices. The action of a fuse is well known. It simply melts and opens the overload circuit when a certain current is maintained for a definite period of time. The bimetal relays are actuated by a bimetal strip placed in the circuit to be protected. The bimetal strip consists of two dissimilar metals (different expansion coefficients) welded together throughout the length of the strip. When they are heated to the same temperature one metal expands more than the other and the result is that the strip bends or curls. The heat may be applied directly or indirectly. Usually the strip is a part of the circuit and is heated by the current passing through it. Indirect heating is arranged by passing the main current through a heater resistance placed close to the bimetal strip. This type of overload is used extensively in motor-starter circuits where the main line current to the armature is passed through the bimetal strip or the heater. Contacts actuated by the bimetal strip open the field coil circuits of the starter relays.

Quick-acting overload relays are used in the plate circuits of transmitting tubes. Plate current flows through the coil while the relay contacts open the high voltage generator field circuit, or if a rectifier is used, opens the circuit to the main rectifier plate control contactor.

When placed in the plate circuit, protection is afforded against plate current overloads caused by improper tuning, short circuits of the high voltage, and loss of bias voltage.

Since the most frequent overload is due to improper tuning, this can usually be quickly remedied and it is not necessary to remove all voltages by shutting down the generator or the rectifier unit.

Master oscillator plate overload relays are used in a slightly different manner. In any event the coil of the relays always carries the master oscillator plate current but the contacts may either shut down the motor-generator or rectifier or simply remove plate screen and perhaps grid bias by opening the generator field circuits or the rectifier plate circuits.

Where bias overload relays are used the coils generally are in the negative side of the bias voltage supply line to protect the circuit against shorts and grounds. The contacts operate to shut down the motor-generator or remove rectifier plate voltages. These contacts are in series with the coil of the master relay.

Fuses are placed in the power line, control and heater circuits, and usually in the high voltage circuits. When used in the high voltage circuits they will be mounted in boxes attached to the motor generator units.

Most high frequency transmitters use a bimetallic relay for protection of the constant temperature compartment. Its contacts open the heater power supply circuit if the compartment temperature rises above about 70° C.

When rectifiers are used, quick-acting overload relays may be found in both high and low voltage a. c. circuits to protect these circuits from shorts, grounds, and faulty rectifier tubes. The coils of these relays are placed in series with the circuits to be protected and the contacts operate in the master relay coil circuit.

INTERLOCKING CONTROL CIRCUITS

Plate or screen voltage must never be applied to a transmitting tube unless it has the correct grid bias. Full filament voltages should not be applied to high power water-cooled tubes until they have warmed up for a definite length of time at a lower voltage. Filament voltage MUST NEVER be applied to water-cooled tubes UNLESS WATER IS FLOWING THROUGH THE WATER JACKETS AT THE CORRECT PRESSURE. Plate voltage must not be applied to mercury vapor rectifier tubes until they have been warmed up by the filament current for a definite length of time. Other restrictions on the manner in which tubes may be operated exist in current practice and additional restriction will probably apply to tubes incorporated in future transmitters.

All application of voltage to the various circuits of a transmitter is controlled by the interlocking control circuits. This control is exercised through the medium of various types of slow acting and quick action relays connected in many different ways.

Although all transmitters of the same general type, power output, frequency range, etc., may use the same tube line-up and therefore must operate under control restrictions, there is no such thing as a standard control circuit for all transmitters.

LOCATING TROUBLE IN TRANSMITTERS

Knowledge of the operation of the r. f. circuits and the operating sequence of the power and control circuits provides the best possible means of locating a circuit which is causing trouble. In most cases, location of the trouble will involve tracing out several circuits. The less familiar you are with these circuits the more time you'll waste in learning them before you can begin looking for the trouble.

TRANSMITTER TROUBLE-SHOOTING

Most transmitters are basically the same in operation. The various circuits and devices used may be somewhat different in design or operation but the fundamental theories of radio circuit and control circuit design apply to all transmitters. For this reason, a thorough knowledge of one or two transmitters in common use will allow a Radioman to service any other model with little or no difficulty.

Transmitters are furnished with many visual INDICATORS which can be depended upon to give a valuable clew as to which circuit is faulty when trouble develops. These indicators are the voltmeters, ammeters, pilot lights, relays, fuses, etc.

The method to use in trouble-shooting is simple:

1. Determine which of the above-mentioned indicators are affected by the trouble.

2. From among the devices affected, pick out the one which controls the others or which would have the most effect on all the others. For instance, a plate starting

relay will control a plate running relay and unless it (the running relay) closes, the plate voltage will be low.

Again, both the generator field relay and an overload relay may be open. The overload relay may control the field relay. There will not, as a rule, be any indication of plate current if there is no indication of grid current and they will both be affected by a bad tube.

3. In the circuit of the one device which seems to control all the rest, pick out the most likely sources of trouble and check them visually or with an ohmmeter. Use the ohmmeter if possible.

4. If checking these does not disclose the source of trouble check the rest of the circuit, paying particular attention to terminal contacts, wires, relay coils, condensers, etc.

KEEP THESE RULES IN MIND

1. Always take the proper precautions when working on high-voltage circuits. Never work alone.

2. Never trust a bleeder resistor to drain a filter condenser of its charge. It may open up and cause you to get a fatal shock.

3. Always reset the overload relays. Don't forget that there is probably one in the starting box.

4. Always be sure that switches are properly seated. Many of them carry auxiliary contacts which make the transmitter inoperative if they do not make contact.

5. Remember that the meter may be at fault.

6. When the transmitter fails to key, always check the keying relay, both the plunger and contacts, before looking anywhere else for the trouble.

USE OF THE OHMMETER

This instrument is an invaluable aid in transmitter servicing. There are certain precautions involved in its use which should never be overlooked:

1. Never connect an ohmmeter to a circuit unless the circuit has been deenergized. Power should first be removed from the transmitter by opening the main line switch before testing any control circuit.

2. Always set the ohmmeter to zero by shorting the test prods and adjusting the variable resistor until the meter reads zero resistance.

3. When making tests, especially when using the high resistance ranges of the meter, be careful not to grasp the test prod points in the fingers as this causes an inaccurate reading.

4. Always short-circuit and ground transmitter filter condensers before using the ohhmeter to make condenser tests.

If an accurate resistance measurement or continuity test is to be made on any device or circuit, you must first be sure that the test is not being made through a parallel "sneak" circuit. A good example of this is in the keying relay circuit of the TBK transmitter (fig. 131). The keying relay is K–1 and the buffer relay is K–2. A test across the terminals of either of these relays would show continuity whether the relay was open or not. Resistance will always be lower than it should be if there is a parallel sneak circuit around the resistance.

It is often a tedious job to remove the connections from the terminals of relays or switches because the terminals are not always accessible. Many times the circuit can be tested, either from the transmitter terminal board or from some other point in the circuit which is more accessible than the parts to be tested. It is necessary to isolate the circuit of which the device is a part, after which the circuit as a whole may be tested. If trouble is indicated by the ohmmeter test, one of the test prods can be left connected to a terminal of the circuit while the other prod is used to make a point-to-point test.

For instance, in the keying system just mentioned, the circuits can be tested with an ohmmeter from terminals 10 and 11. First, open the line switch in the starter box. Close the start-stop switch and the test key. Test the circuit consisting of the keying relay coil K–1, S–1–C, S–9–B, and S–2–A, contact K–3 (normally closed) and the resistor R–30 by removing the resistor R–17 and opening the keying relay contact K–3 by hand. Other circuits may be tested in a similar manner.

WHEN TRANSMITTER FAILS

If the transmitter fails to start, determine which circuit is not functioning by watching the various indicators in the transmitter and starting box or rectifier unit. In general, the master relay should operate first. The door interlocks and probably some overload relay contacts are in its circuit.

When it is impossible to start the transmitter ALWAYS CHECK THE DOOR INTERLOCKS AND OVERLOAD RELAYS BEFORE DOING ANYTHING ELSE. NEVER OVERLOOK THEM. If no relays in any of the circuits operate, the trouble is probably due to lack of power caused by an open line switch, open fuse, dirty or broken terminal connection or possibly an open overload relay. The fuses and switch may or may not be in the transmitter room.

If the transmitter starts but all voltages are not available from the motor generator, check the first circuit in the operating sequence which lacks voltage. For instance, plate voltage will not come on until bias voltage is available. Check the bias interlock, plate generator field circuit, fuses, switches, plate voltmeter, generator brushes, etc.

If all voltages are not available from the rectifier, check by determining which voltage is due next in the operating sequence. You will probably locate the cause of the trouble in the coil circuit of the relay which controls this voltage, or in some circuit which is interlocked with it.

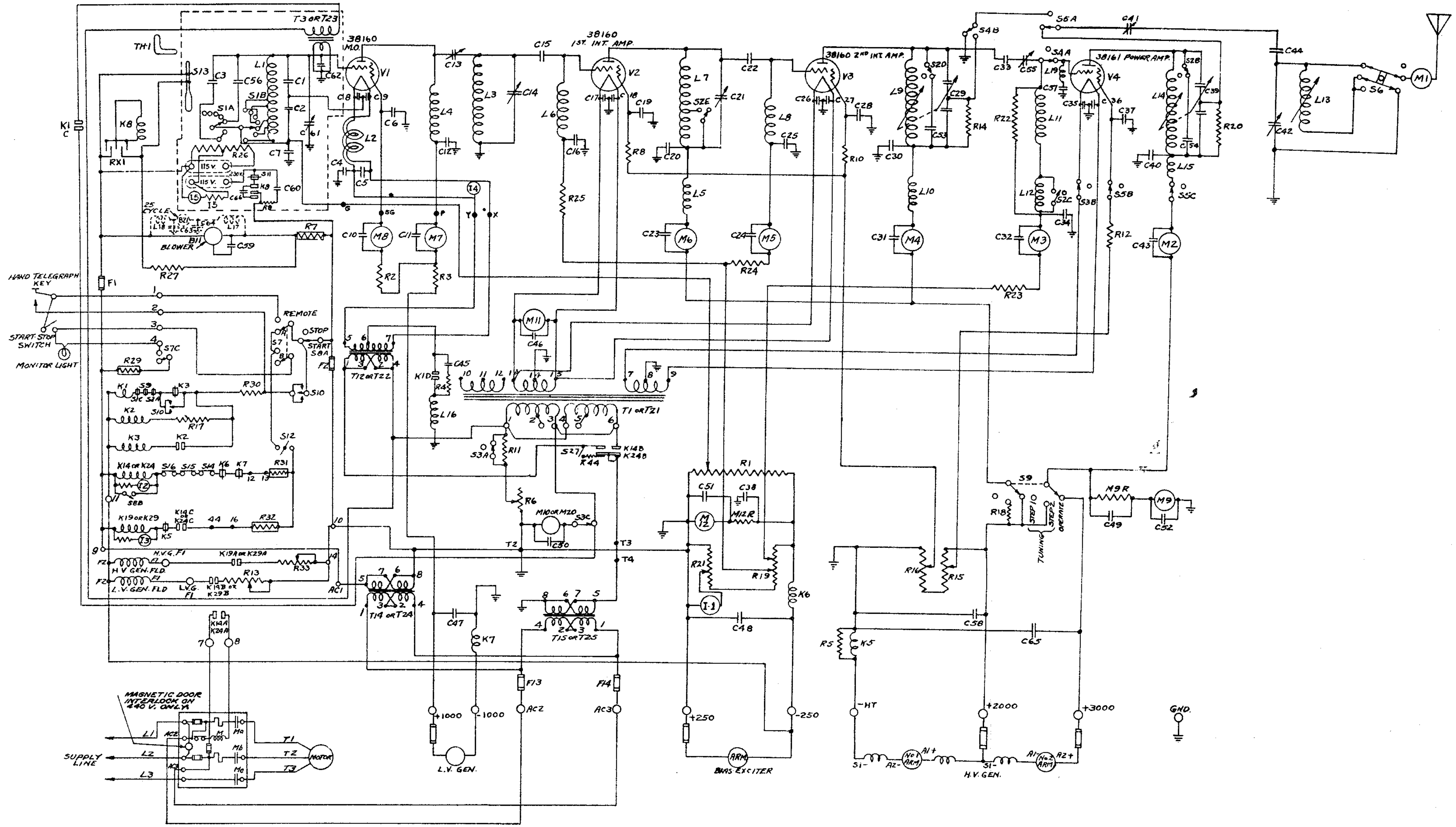


Figure 131.—Schematic of a TBK transmitter.

The most likely sources of trouble are defective tubes, bad relay contacts, overload relays which have kicked out, burned out voltage-dropping resistors, dirty or broken terminal connections. The best test for a defective rectifier tube is to replace it with one known to be good. Very low room temperature will prevent a mercury vapor rectifier tube from igniting properly and very high temperature will cause it to flash back. Make sure the temperature around the base of the tube is within the proper limits if tubes persist in failing.

Radio frequency circuit faults can be located by looking for trouble in the circuits of the last tube in the line-up which fails to operate properly. If all stages are dead but voltages seem normal, check the keying relay and its contacts. A very small particle of dirt between relay contacts will prevent the set from keying. When the trouble is not due to faulty keying it must be caused by a failure of the oscillator circuit to function properly.

When one or more, but not all, stages are dead, check the circuits of the dead stage which is closest in the line-up to the oscillator. The trouble may be in the excitation (grid) part of the circuit, screen or plate circuits or in the tube itself. The meters will usually give an indication of the portion of the circuit in which trouble will be located.

When tuning seems faulty the trouble will usually be found in the tuned circuits themselves. Dirty contacts on tuning coils or condensers will cause the plate to flicker when tuning through resonance. Inability to tune to the proper frequency denotes a loose mechanical coupling in the tuning system. The same trouble may be caused by a faulty range switch.

Do not overlook the possibility of a SECTION in a fixed tuning condenser (often used to extend the range of the circuit) becoming short-circuited. Many of these high voltage fixed-tuning condensers are made up of two or more sections connected in series and all enclosed in one case. A capacity test should indicate the trouble.

Overheated tubes usually indicate improper tuning, a short-circuited or open antenna circuit, improper bias or a poor tube. It is possible for the antenna to be grounded, yet for the power amplifier plate current to either rise, lower, or remain practically constant. If the plate current remains constant the tube will overheat but the overload relay will not drop out. No reliance can be placed on the overload relay for protection against a short-circuited antenna circuit.

If the trouble seems to be in the tube, as indicated by low plate and grid current when everything else is normal, try a new tube in the socket. If plate current is abnormally high or grid current reversed the tube may be gassy. This condition would also be indicated by a pinkish or blue glow between the tube elements. Do not mistake the purple fluorescence, sometimes visible in the form of a cloud near the glass envelope, for the gassy ionization glow. Fluorescence is usually due to a slight defect in the manufacture of the envelope. It will vary somewhat in intensity while tuning, will not affect the plate current, and has no detrimental effects.

EXAMPLES OF TROUBLE-SHOOTING

As concrete examples of how the results of study of the transmitter circuits and the method of trouble-shooting outlined above can be used, the following examples are given and worked out. These two examples demonstrate the use of the system which uses a motor-generator set for power supply. Each separate step in the process of elimination is shown. After a little experience with this sort of work many of these steps can be eliminated, but in this case they serve to show more clearly the line of reasoning to be followed.

EXAMPLE:

Suppose the main power amplifier fails to draw plate current. The grid current is normal, and plate voltage normal at 3,000 volts.

A check discloses the following:

1. Filament circuit is functioning properly or the tube would not light nor could grid current flow if the filament center-tap on the transformer secondary were open.

2. Bias and excitation voltages correct or grid current would not be normal. Furthermore, loss of bias would be indicated on the bias voltmeter and, if plate voltage were applied, the plate overload relay would have kicked out. This would have caused the entire transmitter to be dead since the overload relay would open the field circuits of both high voltage generators.

3. Plate current will not flow if EITHER the screen or plate circuits are OPEN.

4. Study of the circuit shows that all screen voltages and the plate voltages for the intermediate amplifiers are obtained from the 2,000-volt armature and that this armature is connected in series with a 1,000-volt armature to supply 3,000 volts to the plate of the main power amplifier. Both of these armatures can be checked with the plate voltmeter by taking readings with the tune-operate switch on step 2 and operate where the meter should read 2,000 and 3,000 volts respectively.

5. The intermediate amplifiers could not operate CORRECTLY if the 2,000-volt voltage divider were open nor if the tune-operate switch failed to make normal contact to these circuits. They would operate, but not correctly, if the negative end of the voltage divider were open.

6. The trouble now is indicated as being in either the plate circuit, between the tune-operate switch and the plate of the tube, or in the screen circuit, between the voltage-divider tap and the screen. It may be a bad connection, broken wire, open resistor, defective high-low power switch, or a broken lead to plate or screen in the tube envelope.

7. A short-circuited plate supply would have been indicated by a plate overload relay kicking out, a blown fuse and probably by violent sparking at the point of short-circuit. Any one of these would prevent the voltmeter from indicating.

8. The circuits should now be checked with ohmmeter. The quickest check is from the + high-voltage terminal to the tube itself. First, make sure the motor-generator is shut down and that the filter condensers are discharged. If a test from +3,000-volt terminal to power amplifier plate fails to reveal the source of trouble, check the screen circuit from +2,000-volt terminal to the screen connection on the tube. One of these tests should reveal an open circuit. The exact location of the open circuit can now be found by a point-to-point test from the plate or screen of the tube along the circuit, until the open is found.

If these tests did not locate the trouble it would no doubt be in the tube itself. Trial of a good tube should prove this. The tube was not tested first since grid current was normal and filament emission was assumed to be good.

Bypass condensers were not suspected because failure of one of these condensers would cause the plate overload relay to trip out and because a short circuit in a bypass condenser across 2,000 or 3,000 volts is self-evident.

EXAMPLE, involving control circuits:

Suppose that with the motor up to normal speed a very low voltage (100 to 150 volts) was indicated on the plate voltmeter and little or no voltage registered on the bias voltmeter.

A check discloses the following:

1. Since two separate generators are affected the trouble must be common to both machines. This practically eliminates high voltage fuses and all brush rigging except the 250-volt armature.

2. The low-plate voltage read on the plate voltmeter

would indicate that the generator field circuit was open and that the voltage was present due to the action of the residual magnetism in the generator field poles.

3. The plate overload relay contacts control the generator field relay, SO MAKE SURE THE PLATE OVERLOAD RELAY IS NOT TRIPPED OUT.

4. Inspection of the diagram (fig. 131) shows that all the high voltage generator fields are excited by the 250-volt armature of the low voltage generator. The field circuits are controlled by the field relay contacts K–9–A and K–9–B. In series with the coil of the field relay K–9 are the contacts of the plate overload relay K–5, contact K–4–B of the master relay, and possibly a voltage-dropping resistor.

5. Since the motor is running the master relay, its supply circuit must be operative. Inspection of the field relay K–9 will show whether it is open or closed. In addition, the plate voltage pilot light acts as a check on the plate overload relay contacts and contacts K–4–B of the master relay. Inspection of the relay was necessary since the pilot light would glow whether the relay coil has an open circuit or not as long as the correct voltage was across the light.

6. Assume that the field relay is closed properly. Indications are that the trouble is in the field circuit itself.

7. Shut down the motor generator. Test with the ohmmeter from terminals HVGF–1 (high voltage generator field) to LVGF–1 (low voltage generator field).

8. With the motor shut down the field relay should drop out and the test should indicate the resistance of the two generator fields connected in series.

9. Determine which contacts of the pairs at K–9–A and K–9–B connect to the field rheostats, and test the rheostats and connections between these two contacts.

10. Test the contacts K–9–A and K–9–B by means of whichever of the following two methods is easier:

(a) Short-circuit contacts K–9–A and start the motor.

If no plate voltage is generated shut off the motor. Short-circuit contact K–9–B and repeat as above.

(b) Put a piece of paper between contacts K–9–A, connect the test prods to the same contacts and close the relay by pushing on the relay armature (not its contacts). If continuity is not indicated repeat the process but with the paper between contacts K–9–B and the test prods across these contacts.

11. Check wiring between transmitter and generator by testing between terminals *lr*, +250, and —250 in the transmitter while the transmitter is shut down. Use the 10-volt scale. Turn the armature over sharply by hand and if the armature, brush rigging, and fuses are in good working order a small voltage will be generated and can be read on the voltmeter.

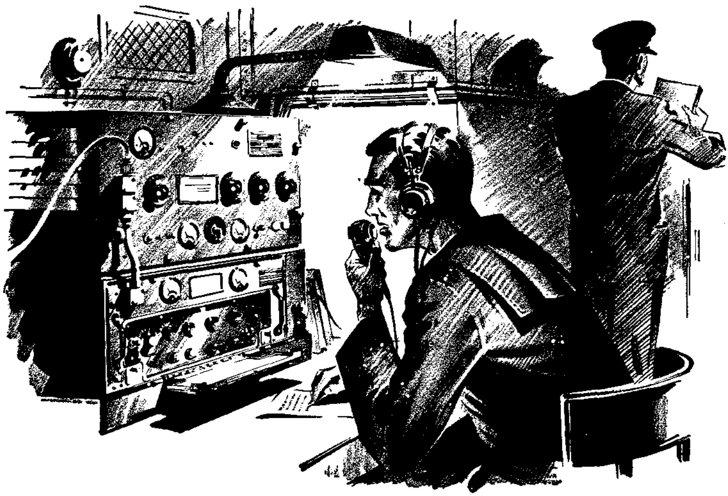
This test can be used for ANY of the armatures in the motor-generator set. Use slightly higher voltmeter ranges for testing high voltage armature circuits and a lower range for motor and slip ring circuits. Rectifier control circuits are always interlocked so that the different circuits are energized in the correct sequence. Thus the control circuit rectifier is first energized and filaments are brought up to operating temperature. The bias rectifier supplies d. c. bias potentials, but cannot possibly supply plate voltage unless the proper d. c. bias is first available.

Many of the relays have pilot lights connected across their coils. In addition, it is generally possible to watch the operation of the relays and of the rectifier tubes.

When the transmitter does not operate due to a voltage failure the relay which controls the application of this voltage should be watched to see if it operates properly. If the relay has closed, its contacts should then be thoroughly examined. If it has not closed it then becomes necessary to check the circuit which energizes the relay coil.

QUIZ

1. What do overheated tubes usually indicate?
2. Where will trouble usually be found when tuning seems faulty?
3. Why should a bleeder resistor used to drain a filter condenser never be trusted?
4. What is the purpose of safety or door interlocks?
5. Why is the oscillator tube usually supplied with power from a separate armature or rectifier?
6. When the antenna has been tuned to approximate resonance what happens to the power amplifier plate current?
7. When may electron-coupled oscillators compare favorably in stability with crystal-controlled oscillators?
8. What is the most desirable cleaning agent for crystals?
9. Why should care be exercised in removing a crystal from its holder?
10. What is the cause of most trouble in tuning HF transmitters?
11. When feeding an antenna through a trunk, will the antenna readings be the same at the transmitter and the base of the antenna proper?
12. What is the purpose of using stand-by operation on rectifier filaments?
13. What should be done to filter condensers before making an ohmmeter test?
14. What will cause the plate current meter to flicker when tuning through resonance?
15. What type of overload relays are used in the plate circuits of transmitting tubes?
16. What is the purpose of the transmitter frequency chart?
17. What is the function of the electrostatic shield?
18. What is the purpose of any rectifying device?



CHAPTER 9

RADIOTELEPHONY

CODE TO VOICE

You already know that a continuous wave of radio frequency can be interrupted by a key, thus transmitting short and long bursts of r. f. oscillation to carry a message. The principle of this type of transmission is as simple as breaking a beam of light to send a visual message.

When radio was adapted to voice, several other elements of transmission had to be considered. The major problem was that of transforming sound waves into electrical impulses which, upon being received, would have the same frequency, magnitude, and phase as the original sounds. To do this, two characteristics of the continuous wave were considered: amplitude and frequency. It was found that by varying either of these (a process called MODULATION), radio waves could be made to match the rise and fall of voice tones. These waves, in turn, could be converted into the original sounds. Amplitude modulation was the first type developed and is still the most widely used in Navy radiotelephony.

AMPLITUDE MODULATION

This type of modulation may be defined as the variation of the strength of the radio frequency at an audio rate. In other words, the r. f energy has to increase and decrease in power according to the audio frequencies. If your voice is high, the r. f. energy must increase and decrease according to the varying frequency of your voice. If your voice is loud in volume, the radio frequency energy must increase and decrease by a larger percentage than if the audio note were soft. In short, the r. f. variations must correspond in every respect with the a. f. variations.

Figure 132 is a block diagram of a typical radiotelephone transmitter. Observe that the final stage of the transmitter shown in an r. f. power amplifier, the same as was found in the c. w. transmitter. A c. w. transmitter is keyed by controlling the voltage on the plate or the grid of the final amplifier with a key. In radiotelephony you want to VARY the output of the transmitter, instead of merely turning it off and on, as in c. w. transmission. This can be done by varying the voltage on one of the electrodes of the final r. f. power amplifier tube.

The problem, then, is to get the plate voltage varied at an audio frequency before the signal enters the antenna for transmission. The first step is to produce an AUDIO VOLTAGE. This is the job of the microphone. Here's what the mike is up against: it can create only a small voltage (usually less than one volt). The plate voltage of the r. f. amplifier, on the other hand, is very high. If you add this small audio voltage to the high plate voltage you get only a very small variation of the plate voltage. For this reason, it is necessary to AMPLIFY the output of the microphone by first feeding it into the grid of a class A voltage amplifier, merely to step up the voltage. (In figure 132 you can see this amplifier, labeled "speech amplifier.") It then goes for final build-up to a second amplifier, called the MODULATOR. This modulator can be any type of audio power amplifier capable of providing sufficient undistorted power.

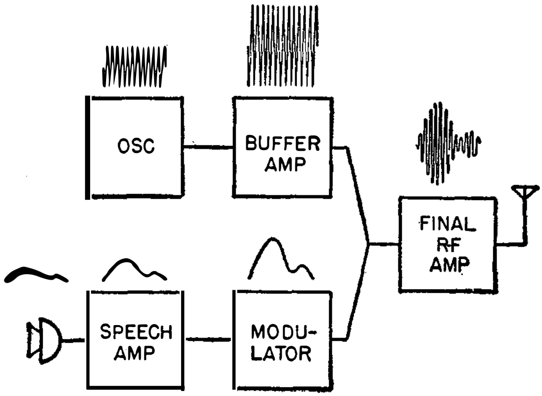


Figure 132.—Block diagram of amplitude modulated transmitter showing formation of modulated wave.

Once the audio frequency is built up by the speech amplifier and the modulator, it is then combined with the r. f. carrier wave. (As you learned in the chapter on transmitters a CARRIER WAVE is simply r. f. oscillations without modulation, the same as you have in ordinary c. w. transmission.) The effect of this combination you can see in figure 132. You now have a signal in which the plate voltage rises and falls at the audio rate.

In short, the microphone output which was originally too weak to have much effect on the carrier, has been strengthened until it controls the wave form which is launched by the antenna. Thus the carrier is modulated, and since modulating the carrier in manner varies the strength (amplitude), this method is called AMPLITUDE MODULATION.

AUDIO COMPONENTS

Figure 132 introduced you to those parts of a radio-telephone transmitter which produce audio frequencies. A brief explanation will give you a general knowledge of how these audio components—microphone, speech amplifier, and modulator—operate.

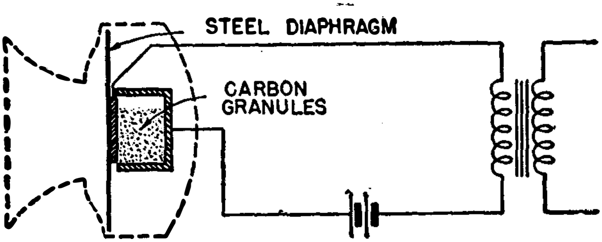


Figure 133.—Carbon microphone.

The microphone generates the audio signal. The most widely used type is the CARBON MICROPHONE (fig. 133), which in effect is a variable resistance. Connections are made to a small container filled with carbon granules. Attached to this container is a flexible diaphragm which sets up a vibration when a voice strikes it. The vibration of the diaphragm compresses and releases the carbon granules, thus changing the resistance of the microphone. As the resistance changes, the current in the microphone circuit changes. In this manner, the voice creates a fluctuating current in the microphone circuit.

The mike illustrated in figure 133 is known as a single-button carbon microphone, the word "button" referring to the small container which holds the carbon granules.

The DYNAMIC MICROPHONE (fig. 134) is a more modern type. The coil which is fastened to the diaphragm moves in and out in accordance with the voice impulses, the wires in the coil cutting the magnetic lines of force set up by the permanent magnet. The voltage induced in the moving coil varies exactly as the speech or sound impressed upon the diaphragm.

The dynamic microphone is more rugged than the carbon granule type, but it has the disadvantage of low voltage output.

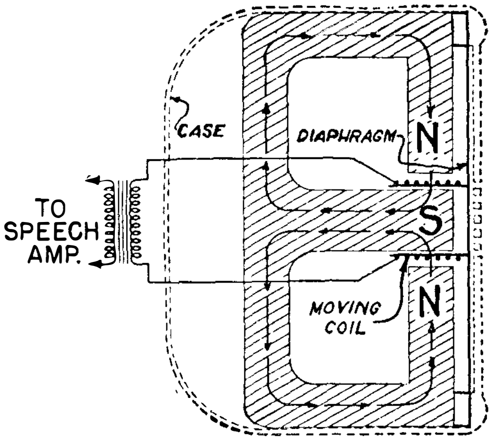


Figure 134.—Dynamic microphone.

The SPEECH AMPLIFIER, as previously explained, prepares the audio output of the microphone for use in the modulator stage. As you can see in figures 133 and 134, the output of either type of microphone can be coupled through a transformer to the grid of an audio amplifier. The transformers shown in these figures have a very high turns ratio in order to step up the voltage. Therefore, any small variations of microphone current in the primary of such a transformer will develop a voltage across the secondary. This voltage is then applied to the grid of the speech amplifier. When a DYNAMIC microphone is used, two and sometimes three speech amplifier stages are required to raise the weak audio voltage to a level suitable for the modulator stage.

The MODULATOR provides the power needed to vary the carrier wave amplitude. This variation, of course, follows the pattern of the sound which originally entered the microphone. The modulator is always an a. f. power amplifier, and may either be a single-tube or push-pull type. The latter is capable of furnishing much more power with greater efficiency than the single-tube amplifier.

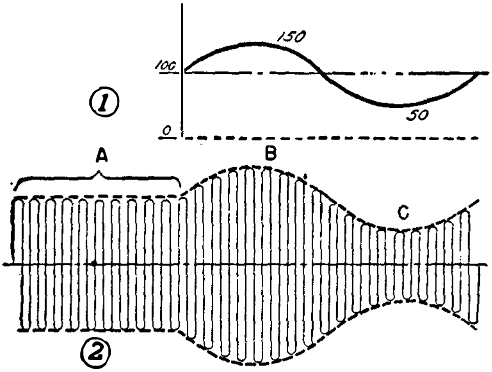
PERCENTAGE OF MODULATION

The amount of modulation of a wave has a lot to do with the effectiveness of the intelligence it carries. After all, a receiver can reproduce only as good a signal as the transmitter sends. When the modulation is too great, or too small, the incoming signal will naturally be imperfect. If it is overmodulated, the signal will be distorted. If it should be undermodulated the signal may be strong but the voice it carries will come in weak.

The amount of modulation is referred to as the degree or percentage of modulation. This is simply a measurement of the maximum amplitude of the wave over the original value of the carrier wave. You can understand this by looking at figure 135. Section *A* in the illustration shows the original value of the carrier wave. This portion is a continuous wave with constant amplitude. Sections *B* and *C* show you the effect of modulation. At *B* the amplitude has increased considerably, and at *C* it is at a low value.

The wave form sent out by a transmitter is directly affected by the amount of variation in the total voltage at the final r. f. amplifier stage. This variation, in turn, depends upon the ratio of audio frequency to direct current voltage. For example, if the d. c. plate voltage to the r. f. amplifier is 100 volts, and the a. f. voltage is 50 volts, the two voltages will add (when they are acting in the same direction) to give 150 volts. On the other hand, when they are acting in opposite directions, they will subtract to give 50 volts. The plate voltage on the r. f. amplifier will vary between 50 and 150 volts. (This can be seen in part 1 of fig. 135.) Since the variation of 50 volts on either side of the d. c. voltage is one-half of the d. c. voltage of 100 volts, the transmitter is said to be modulated 50 percent.

Now, you've been told that the wave form (r. f. output) of a transmitter is affected by variations in the total voltage at the final r. f. amplifier stage. Look at figure 135



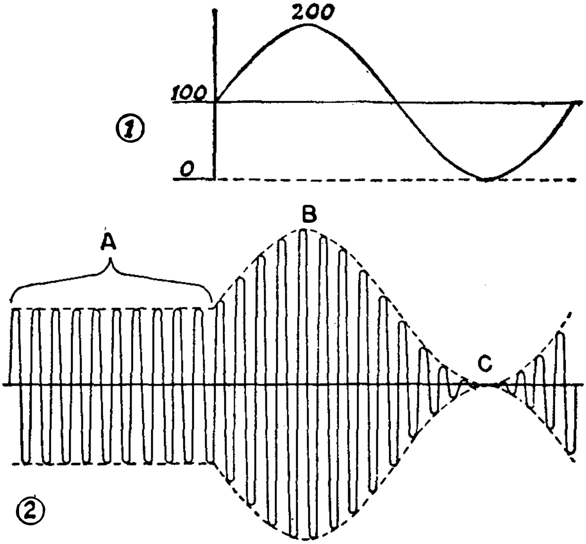
① *Values of instantaneous plate voltage.*
② *Modulated r-f wave.*

Figure 135.—Illustrating 50 percent modulation.

again. The carrier wave, produced with only d. c. voltage on the plate of the r. f. amplifier, is of constant amplitude. As soon as an a. c. voltage is applied in series with a d. c. voltage (when the modulator is in operation) the plate voltage, and hence the r. f. output, begins to vary. At *B*, the r. f. wave has reached an amplitude 50 percent GREATER than during period *A*. When the plate voltage decreases, the r. f. output decreases. At *C* the r. f. wave has reached an amplitude 50 percent LESS than the unmodulated wave at *A*. Thus, again, the degree of modulation may be defined as the amount of variation of the modulated wave compared with the unmodulated wave.

If the d. c. voltage were 100 volts and the audio voltage also 100 volts, the instantaneous plate voltage would vary between zero and 200 volts. (This is shown in fig. 136.)

Whenever the instantaneous plate voltage varies between zero and TWICE its unmodulated value, there is 100 percent modulation. The resulting wave form can be seen in figure 136.



① *Values of instantaneous plate voltage.*
② *The modulated r-f wave.*

Figure 136.—Illustrating 100 percent modulation.

It is important that amplitude be varied as much as possible, because the detector output in a receiver varies with the amplitude variation of the signal received. The more nearly the variations follow the sound pattern of the voice speaking, the better the receiver can reproduce these sounds. You'll find that a comparatively low-power station—WELL MODULATED—will often produce a stronger signal at a given point than a much higher powered, but poorly modulated, transmitter located the same distance from the receiver. However, there is a limit to the percentage of modulation which should be used. This limit is 100 percent, and here's why.

Assume that a given transmitter is actually modulated 150 percent. With a d. c. voltage of 100 volts, this would require an audio voltage of 150 volts. The two would add together to give 250 volts, down to minus 50 volts, and

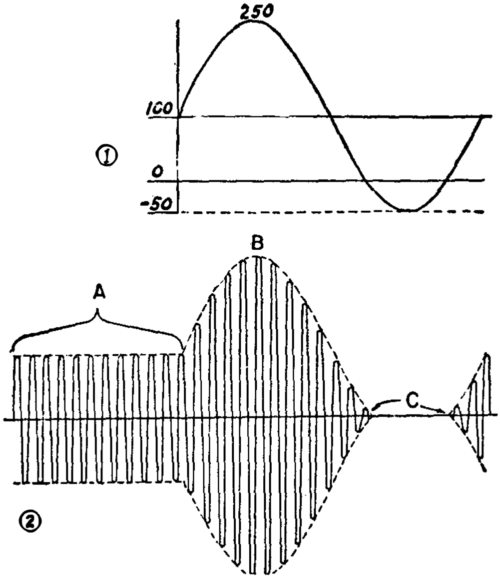


Figure 137.—Overmodulation.

then back to zero. (See sec. 1 of fig. 137.) During the swing from zero to 250 volts and back to zero, plate current would flow. BUT DURING THE SWING FROM ZERO TO —50 VOLTS AND BACK AGAIN TO ZERO, LITTLE OR NO PLATE CURRENT WOULD FLOW. During this period the transmitter, for all practical purposes, would be shut off. This condition produces an overmodulated wave, as illustrated in section 2 of figure 137. The portion of the wave labeled *A* in the figure is the unmodulated carrier wave. With the modulator in operation, the r. f. wave would increase to the value shown at *B,* and would then decrease to zero. Over the region *C,* the plate voltage would be negative and there would be no output from the tube.

This is why a receiver will cut out when you shout into a radiotelephone microphone. The audio input is too great, resulting in an overmodulated wave. Thus, you can see that modulation of a wave should never exceed 100 percent.

SIDE BANDS

In figures 135 and 136 you studied illustrations of an r. f. wave modulated at different percentages. Such a wave is actually a combination of several frequencies. You can't tell, merely by looking at an illustration of a wave, what frequencies are combined to give it the shape it has. However, by involved mathematical analysis these frequencies can be determined. As a practical example, if the r. f. carrier is 100 kilocycles and the audio frequency is 1,000 cycles (1 kilocycle), the wave will contain the following frequencies:

Fundamental frequencies	*Second harmonic*	*Sum frequency*	*Difference frequency*
100 kc.	200 kc.	101 kc.	99 kc.
1 kc.	2 kc.	......	......

Harmonics other than the second are produced, but they are very weak and easily dispensed with. All of these frequencies are present in the plate circuit of the final r. f. amplifier, but the plate circuit is broadly tuned to 100 kilocycles. This means that only frequencies of 100 kilocycles, 101 kilocycles, and 99 kilocycles will enter the antenna through the antenna coupling circuit. The remainder of the frequencies developed will be bypassed. Thus, instead of transmitting only one frequency, the antenna is transmitting THREE frequencies very close together. For all practical purposes, the condition which exists resembles the frequency wave forms shown in figure 138.

The extra frequencies are known as side-band frequencies, or merely side bands. As shown in figure 138, these side bands are separated from the carrier (100 kilocycles) by the amount of the radio frequency (1 kilocycle). Thus, if the audio frequency had been 2 kilocycles, the side-band frequencies would be 98 kilocycles and 102 kilocycles. The higher the audio-modulation frequency, the farther both side bands will be from the main carrier wave.

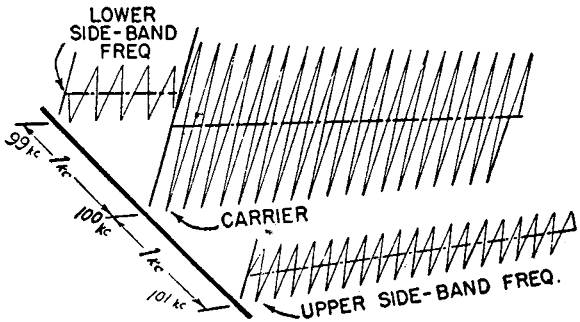


Figure 138.—Carrier wave and its side-band frequencies.

In actual speech, many audio frequencies are used to modulate the carrier wave. There will be a pair of frequencies (one upper and one lower) for each audio frequency, and there will be an entire band or group of frequencies resulting from speech modulation. The graph of such a carrier is illustrated in figure 139 which shows the complex nature of speech impulses. The graph of figure 139 is the wave form resulting from the addition of the side bands to the carrier wave.

If the modulator of a radiotelephone transmitter were turned off, the carrier would continue to be transmitted by the r. f. power amplifier. However, as soon as the modulator is turned on and the r. f. carrier is varied by modulation, the side-band frequencies come into existence. From this you can see that the modulated wave contains more power than the carrier wave alone. The additional power is supplied by the modulator stage, and appears in the form of side bands.

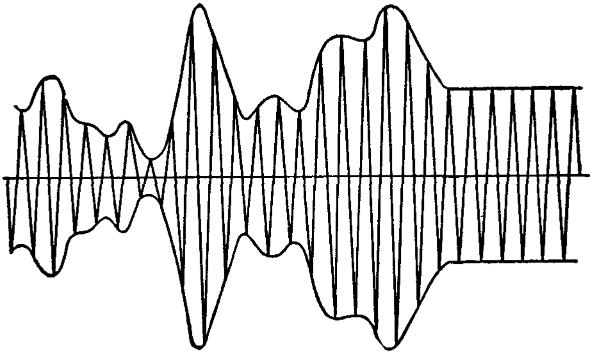


Figure 139.—Radio wave modulated with voice.

METHODS OF MODULATION

There are several methods of amplitude modulation. Fundamentally, the same thing occurs in each: the transmitter r. f. output is varied by applying audio voltages to the carrier wave. Some methods of modulation require heavier equipment and more complicated circuits than others. For this reason, the type of modulation is an important factor when a transmitter is designed for a particular communication job. Naval aircraft, for instance, are often equipped with grid-modulated transmitters since grid modulation requires less equipment than other types, and thus saves space and weight.

The most common type is a method in which the a. f. modulating voltages can be applied to the PLATE of one of the transmitter r. f. amplifiers. This popular method is known as PLATE MODULATION.

In order to produce PLATE MODULATION you apply a. f. power to the plate circuit of an r. f. power amplifier. An amplifier using plate modulation is much more efficient than one using grid or some other form of modulation. Another thing, you'll find it's easier to make adjustments to the transmitter when you use plate modulation. There is also less plate loss in the r. f. power amplifier for a given value of carrier power than in other forms of modulation. It all adds up to this: plate modulation is used to a greater extent than any other.

The simplest method of modulating the plate of the r. f. amplifier is by means of transformer coupling. In figure 140, the a. f. output of the modulator stage is coupled through the transformer *T* to the plate circuit of the power amplifier. The voltage appearing across the secondary *S* of the transformer is an audio voltage. As

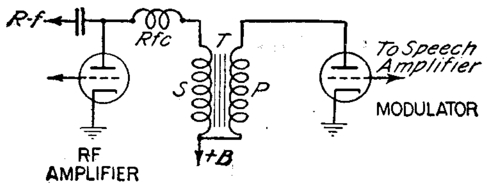


Figure 140.—Transformer-coupled modulator circuit.

such, it is an alternating voltage driving first in one direction and then in the other. This voltage is in series with the d. c. supply voltage, which drives in only one direction. Thus, at one instant, the a. c. voltage and the d. c. voltage will be acting in the same direction and the total voltage will increase. But, at the next instant, the a. c. voltage will have reversed, and the two voltages will then oppose each other. Therefore, the total voltage will decrease. This causes an alternate increase and decrease of the total voltage at an audio frequency. Since this total voltage is the plate voltage, the amount of variation in amplitude of the r. f. wave depends upon the relative amounts of the audio voltage. In other words, the amount of variation depends upon the ratio of audio to d. c. voltages. The greater the audio, the more modulated the wave.

The plate of the r. f. amplifier tube can be modulated by another method using a REACTOR, or CHOKE COIL. You should study figure 141 which illustrates a typical choke-coupled modulation circuit. In this illustration both the plate of the modulator tube and the r. f. power amplifier obtain their d. c. plate voltage through the iron-core choke *L*, called a MODULATION REACTOR. As the plate current of the modulator increases and decreases (at audio

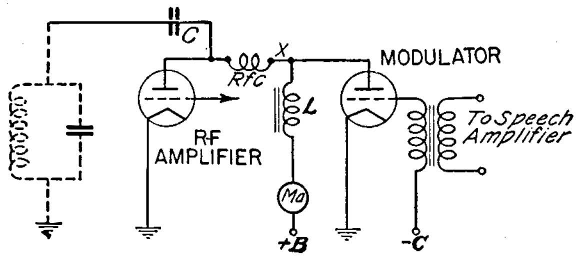


Figure 141.—Choke-coupled (constant current) modulation circuit.

frequencies), a voltage is developed across *L* proportional to the current flowing through it. This voltage is developed across the choke in the following manner. When the plate current from the modulator increases, the expanding magnetic field or the choke induces a voltage which will tend to oppose the change of current. This voltage will buck the voltage applied to the plate or the r. f. amplifier, thereby reducing its plate current. When the modulator plate current decreases, this same magnetic field will collapse and again induce a voltage. This induced voltage will aid the voltage on the plate of the modulated stage and increase its plate current. This produces an alternating voltage and current in the plate circuit of the modulated stage, varying its output in accordance with the audio signal. You should understand that as the current TO THE MODULATOR is increasing, the current to the modulated stage is decreasing, and VICE VERSA. Because of this action, the current indicated on the meter, M_a, will remain practically constant. This system is called the CONSTANT CURRENT system.

GRID MODULATION

When a transmitter uses grid modulation, the grid bias supply to the power amplifier is varied. It's done in this way. The grid bias supply to the power amplifier is usually a fixed value obtained from a separate power source. If it were allowed to remain so, it would pass through the power amplifier, through the antenna coupling, and out into space as an unmodulated wave. However, by introducing audio voltages the grid bias supply can be varied. As you know, audio voltages are alternating voltages. They have the ability to add to or subtract from the fixed grid bias voltage, and so control the output of the r. f. amplifier. The antenna will then radiate a modulated wave.

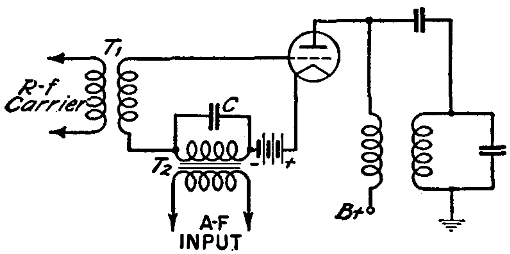


Figure 142.—Circuit for grid modulation.

A circuit using grid modulation is shown in figure 142. You can see that a modulation transformer, T_2, has been placed in series with the grid-return lead of the r. f. power amplifier. The grid bias, as shown, is always negative. The purpose of the condenser C is to prevent current from returning through the circuit and back into the battery. T_1 is a coupling coil used to transfer maximum power from the final stage into the antenna.

Since varying the grid bias of the r. f. stage does not require a great amount of power, a low output class A amplifier is sufficient for grid modulation. In the end, this results in low efficiency. As a matter of fact, the r. f.

carrier output power of a grid-modulated transmitter is about one-quarter that of a plate modulated transmitter.

SCREEN-GRID MODULATION

When you studied the tetrode you learned that a small voltage variation on the screen results in a large increase in plate current. Because of this, modulation can be effected by placing the modulation transformer in series with the screen-grid lead. However, this method limits the percentage of modulation to a low value. If BOTH the plate and screen voltages are modulated at the same time, it is possible to approach 90 percent modulation without too much distortion.

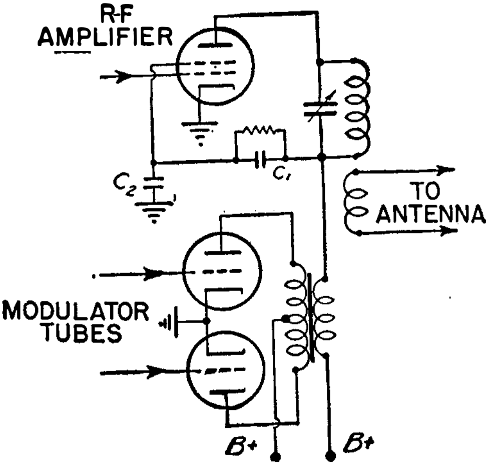


Figure 143.—Circuit for screen-grid modulation.

A circuit of this type is shown in figure 143. Note that the screen-dropping resistor is connected to the plate side of the secondary winding of the modulation transformer. In this way both screen and plate keep the same ratio of voltages to each other under all variations of plate voltage. Capacitor C_1 bypasses the audio voltage around the screen-dropping resistor while C_2 is the usual screen-bypass capacitor.

SUPPRESSOR-GRID MODULATION

When a pentode tube is operated as a class C amplifier, you can get modulation by applying a. f. voltage to the suppressor voltage of that tube. A change in bias voltage on the suppressor grid will change the r. f. output of a pentode tube. Thus by applying a. f. voltage you have a simple method of obtaining modulation. It is difficult to obtain 100 percent modulation, although about 90 percent can be produced. A typical circuit for suppressor-grid modulation is shown in figure 144. The modulator shown in this figure is push-pull.

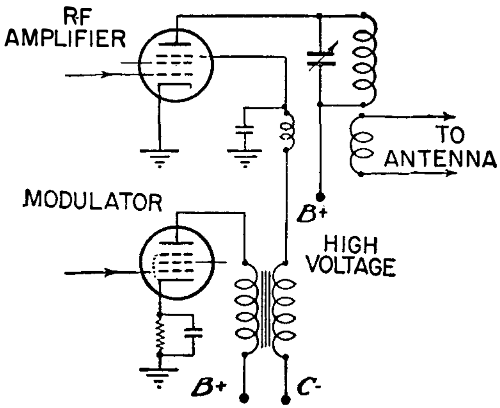


Figure 144.—Circuit for suppressor-grid modulation.

LEVELS OF MODULATION

Amplitude modulation is said to be HIGH LEVEL or LOW LEVEL, according to the stage in the transmitter at which the modulation takes place. If the modulating voltage is applied to the last stage—the power amplifier stage, you have a high-level modulated transmitter. If the modulation is applied to one of the buffer stages, the system is said to be low-level modulated.

High-level modulation gives the greatest efficiency and the least distortion. These two advantages make this circuit especially desirable for use in commercial broadcast transmitters where fidelity of response and efficient operation are of primary importance.

Low-level modulation gives neither high efficiency nor fidelity, but it does have the advantage of requiring a less powerful modulator. No matter which stage is to be modulated, to get 100 percent modulation the speech amplifier must supply 50 percent of the r. f. power of the stage to which the modulating voltage is applied.

Since power will increase in each following stage of amplification, much more power is required to modulate the power amplifier than to modulate a buffer stage. Communication transmitters do not require the high fidelity demanded of broadcast transmitters. In communications the important thing is to get the message through, hence most communications transmitters can use low-level modulation satisfactorily.

QUIZ

1. What furnishes power necessary to vary the amplitude of the r. f. wave in accordance with the sound impulses?
2. Of what use is the speech amplifier?
3. What type of microphone is most widely used in the Navy?
4. What determines the amount of power necessary to modulate a transmitter?
5. What type of modulation is used to a greater extent in the Navy than any other?
6. How may amplitude modulation be defined?
7. What type of modulation is usually found in naval aircraft?
8. What is the reason for varying the plate voltage of the r. f. amplifier of a transmitter?
9. What type of signal does the microphone generate?
10. What is the simplest method of modulating the plate of the r. f. amplifier?

CHAPTER 10

SONAR EQUIPMENT

UNDERWATER BROADCAST

Sonar equipment is similar to a radio broadcasting and receiving station. You are a transmitting station when the sound goes out into the water, and a receiving station when the echo returns to you. The keying interval determines how long or how many times you become a transmitting and receiving station. Although sonar equipment is constantly changing, the basic principles still apply: you transmit sound into water and listen for returning echoes.

Since the introduction of the submarine in modern warfare, efforts to improve methods of detecting and destroying underwater craft have continued. During the past war, echo-ranging with a narrow beam of sound was the best method of submarine detection and the depth charge was considered the most effective means of destruction.

However, wartime antisubmarine warfare (ASW) operations proved two things: (1) "Searchlight" sonar was hampered for lack of a positive means of determining the sub's depth; and (2) the submarine's sturdy construction could withstand anything except a direct hit or very near miss. As a result, a system of attack known as INTEGRATED SONAR was developed, and emphasis shifted from depth charges to ahead-thrown weapons as a means of destroying submarines.

INTEGRATED SONAR

The INTEGRATED SONAR SYSTEM is the most effective antisubmarine system in use by surface craft at the present time. By using an attack director, many features of surface fire control have been adapted to help solve the ASW attack problem.

One of the first requirements of antisubmarine warfare is to locate the sub. The integrated system uses scanning sonar to obtain initial ranges and bearings. Unlike the searchlight gear, scanning sonar covers 360° with each transmission. The sound goes out in an expanding spiral about the vessel and echo information returns as a sound, and as a visual presentation on a scope similar to a radar PPI.

Once the bearing and initial range of the sub is established, another type of sonar equipment determines its depth. The second equipment has a beam which can be depressed, thereby furnishing DEPTH information to be used in conjunction with the scanning sonar's AZIMUTH information. This data is fed into the SONAR RESOLVER, an electromechanical device which rapidly calculates the horizontal range of the target. The resolver also controls the DEPTH RECORDER.

All this information, plus own ship's course and speed, is fed into an ATTACK DIRECTOR which solves the fire-control problem. The director furnishes the course and speed of the target, the course your own ship must steer,

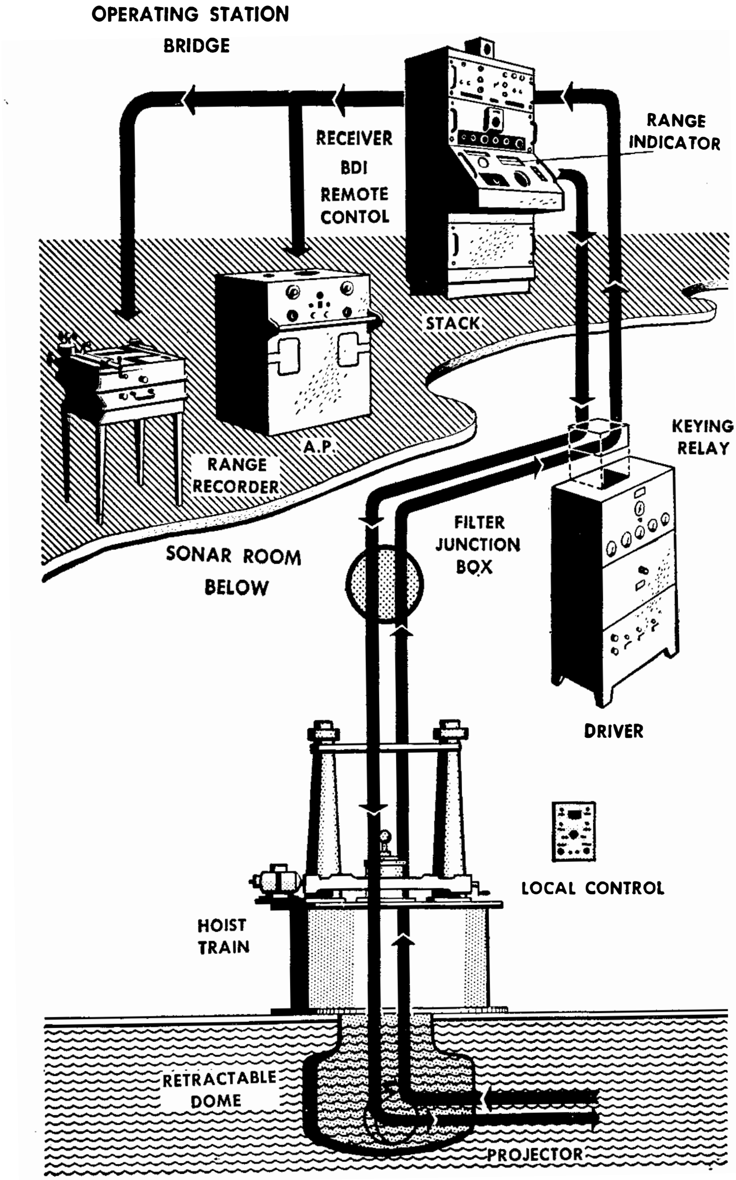


Figure 145.—Learn where they are and what they do.

and the time to fire. To compensate for the sub's last-minute evasive maneuvers, the director determines the angle of train to be set on the ahead-thrown weapon launchers.

THE ATTACK TEAM

Equipment does much to solve the ASW problem, but the operation of that equipment and the final decisions must be made by members of the sonar attack team. This team includes the captain of the ship, men in combat information center (CIC) who plot the course of the attack, the underwater battery plot (UB) from which the attack is directed, and the sonar control room which furnishes the information needed to destroy submarines.

There was a time when antisubmarine runs were conned from the bridge of the attacking vessel. Generally, the ASW officer coordinated and evaluated incoming information which he passed to the officer conning the run, the CO or OOD. Now antisubmarine runs are made from below decks, in underwater battery plot. The ASW officer takes charge of the run, and the OOD serves as a safety lookout topside to make sure the surface of the ocean is clear for the run.

Even so, the ASW officer has a radar repeater (PPI scope) to provide a constant picture of the disposition of other surface units. In addition, there is a scanning sonar repeater to furnish continuous bearings on the target, and, of course, a director to give him the correct course to steer and the correct firing time. The various courses required during an attack are automatically transmitted to an indicator at the steering station; the helmsman simply matches pointers to keep the ship headed correctly. From UB plot the train angle to be set on the ahead-thrown weapon launcher is automatically transmitted by the director and, at the proper time, the order to fire is given by the ASW officer.

The sonar control room (formerly called the sonar hut) provides the information which UB plot coordinates and acts upon. Sonarmen stationed in this space operate scanning and depth-determining equipment, as well as recorders which feed ranges and range-rates into the director.

The equipment which you'll find in sonar control will vary according to the type of ASW vessel to which you are attached. Lighter craft, such as the PC, PCE, PCS, SC, etc., cannot carry the extra weight required for integrated sonar. For this reason you can expect various combinations of equipment. Some ships may have scanning sonar working in conjunction with the range recorder designed for searchlight gear. Others—particularly vessels in the reserve fleets—carry searchlight sonar, range recorders, and associated equipment used in World War II.

You should understand that integrated sonar is simply the latest development in the constantly changing ASW picture. It is not the final answer.

THE CONSOLE

In earlier types of gear the various units were placed one on the other to form a REMOTE CONTROL STACK, known to Sonarmen simply as "the stack." Later this equipment was replaced by a console arrangement, although essentially the same units were incorporated. Both the searchlight and scanning sonars in use today are console models.

One of the units in the console is the receiver-amplifier, similar in many respects to a household receiver of the superheterodyne type. This unit receives and amplifies the returning echo from the submarine, converting that echo into a pitch that you can hear. It does this by converting an ultra-sonic frequency into a sonic frequency. There are a number of controls available for tuning and operating the receiver-amplifier.

Next is the remote control unit which controls the hoisting and lowering of the sonar transducer—that part of the gear, located beneath the keel, which transmits sound into the water and picks up the returning echo. In searchlight sonar the remote control unit also controls the training of the transducer. A remote bearing indicator on this unit tells you the bearing on which the transducer is trained.

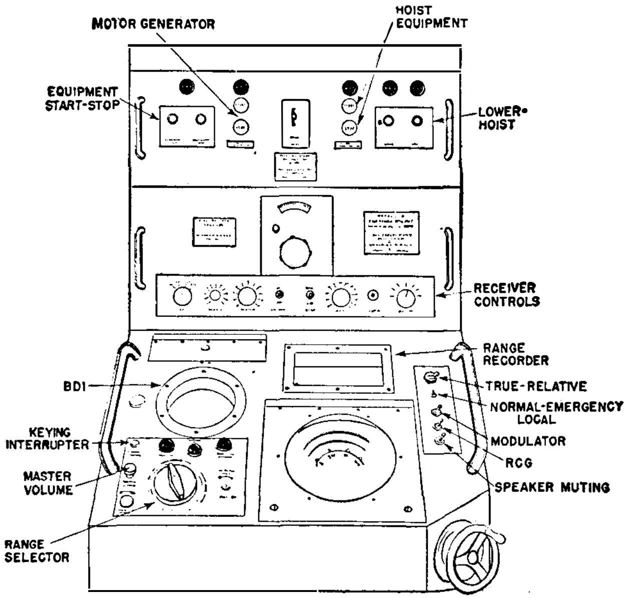


Figure 146.—Sonar console.

Ranges can be read on console models by means of a range indicator. There are several types of range indicator units. In the console type, the range indicator unit is on the same panel as the remote controls. You can use almost any range scale with this type and you can read ranges accurately from 0 to 3,700 yards. With scanning sonar, the PPI scope serves the same purpose.

Other parts of the console include a loudspeaker from which you hear the echo converted by the receiver-amplifier; and a hand key for communication with other ASW vessels, or submarines.

THE SONAR ROOM

The sonar room is located below deck, usually in the bow of the ship, and is sometimes referred to as the lower sound room. It is a separate compartment given over to sonar gear and spare parts for sonar. The hoist-train mechanism, located directly over the transducer, is also in this room. The main units in the sonar room are the driver, the keying relay (located inside the driver), and the filter junction box.

The DRIVER is the transmitting oscillator and is similar to a radio transmitter. This unit is the one which actually makes the transducer vibrate the proper number of times per second to create the transmission of sound sent out into the water.

The KEYING RELAY allows the driver to send out the electrical impulse which will be converted into a mechanical impulse of sound when it leaves the projector. When the driver is not actually keying, this relay keeps the receiver-amplifier connected to the transducer. The keying relay alternately lets the driver and the receiver-amplifier do its work.

THE TRANSDUCER

The transducer changes the electrical energy from the driver into the mechanical energy of sound waves when a transmission is made. It also changes the mechanical energy of the sound waves into electrical energy which you finally hear and see on the scope when an echo is received. It is composed of two parts, a diaphragm and a protective case.

Electric current causes the diaphragm to vibrate at a high frequency. These vibrations put the particles of water into vibration and this is the beginning of the sound beam. When the returning sound—the echo—strikes the diaphragm, the diaphragm vibrates and sends a small current up into the receiver-amplifier.

There are two general types of transducers. One type has nickel tubes in it that expand and contract when surrounded by an electric current. The expanding and contracting ability of the nickel tubes is spoken of as MAGNETOSTRICTION.

The other type of transducer has crystals instead of nickel but it acts in about the same manner. When crystals are used, the effect is PIEZOELECTRIC.

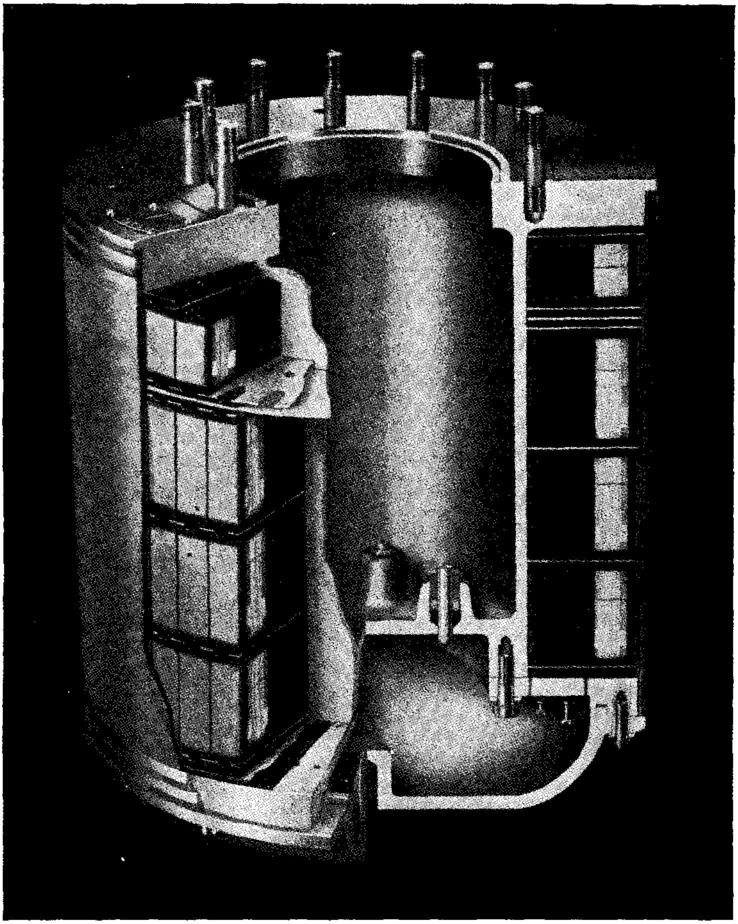


Figure 147.—Cutaway view of transducer.

The transducer in scanning sonar is a cylinder composed of 48 segments. Transmissions go out from all segments simultaneously, and then each segment becomes a hydrophone listening for returning echoes. Each segment "protects" 7.5° of bearing.

Depth-determining equipment uses a scabbard-shaped transducer, located beneath the keel and forward of the azimuth-searching transducer. This scabbard can be tilted to various degrees, but cannot be trained in azimuth. As previously explained, this transducer provides the target depression angle. In order that the transducer be kept on the target and provide accurate information, some means of compensating for the pitch and roll of the ASW vessel must be available. The MAIN BATTERY STABLE ELEMENT serves this purpose. As the ship pitches, for instance, the stable element causes a counter movement which keeps the transducer at the same angle to the horizon.

TRANSDUCER DOMES

When searchlight gear was put into operation, domes were designed to protect the transducer as it moved forward with the ship. Sometimes the dome was shaped like a steel ball, and sometimes it was streamlined, or "fish" type. In addition to protecting the transducer, it cut down the noises that resulted from water swirling around the sharp edges of the diaphragm.

The discussion of domes here largely applies to searchlight transducers. Scanning sonar is also housed in a dome, but there is no need for training the transducer within the dome since scanning sonar searches in all directions simultaneously.

One of the domes used to enclose the transducer is made up of two half-round covers and is called the ball-shaped dome. One cover is of thin corrosion-resistant steel. This half is placed in front of the diaphragm and acts as a sound-transparent window so that there will be no loss of energy when the signal is transmitted. The space between the diaphragm and cover is filled with a liquid.

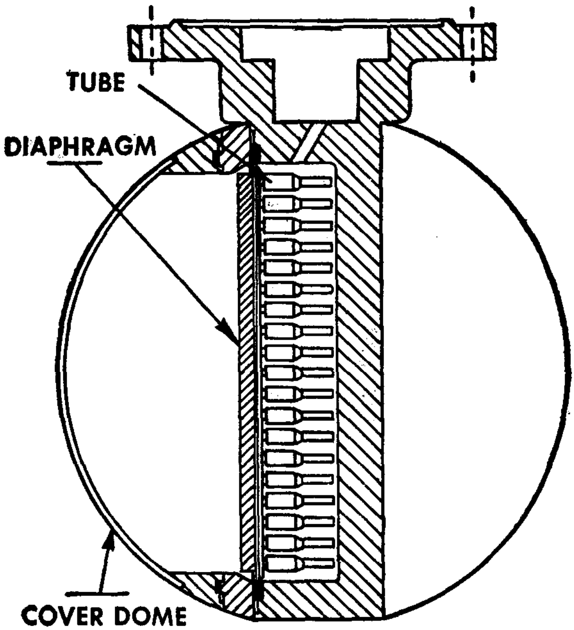


Figure 148.—The ball-shaped dome.

The other half is of heavy steel and is placed behind the diaphragm. This heavy case tends to keep out unwanted signals from the reverse side of the transducer. For instance, it would lessen your own propeller noise when, with searchlight gear, you are trained dead ahead. This ball-shaped dome appears in figure 148.

The entire dome may be lowered into the water and extends about 3 feet below the keel when you are conducting a screening mission. You can hoist it into the sea chest when you do not wish to echo-range.

You will find the fish-type of dome being used on many of the smaller ships. This dome, together with the transducer which is free to turn inside the dome, can be hoisted into the sea chest if one is provided. The fish dome is mounted to one side of the keel and extends several feet below the keel when fully lowered.

The retractable dome is usually installed on the following types of ships—DE, PC, PCE, AM, and PF. The retractable dome is secured to a raft which can be lowered and hoisted either by motor or by hand. If the maintenance man wishes to make repairs to the transducer in the dome, he can hoist the dome into the sea chest and pump the water from it. The dome shown with the hoist-train unit in figure 149 is a retractable dome.

If your ship is fitted with a retractable dome, READ THE FOLLOWING CAREFULLY: Whenever you lower the gear, YOU MUST SEAT IT FIRMLY IN THE LOWERED POSITION BY MEANS OF A HAND CRANK. If the dome is not resting solidly, it will rattle and shake. There is an air release valve on the hoist-train mechanism that will allow accumulated air to escape from the dome. You merely open the valve and let the air flow out. As soon as the air stops coming out, water will begin to come out. When this happens, turn off the valve immediately. YOU MUST RELEASE THE AIR FROM RETRACTABLE DOMES. Enough air can accumulate inside the dome to completely quench and absorb the outgoing transmissions.

The front part of the retractable dome is provided with a sound-transparent window of corrosion-resistant steel, two-hundredths of an inch thick. A corrosion-resistant steel bulkhead near the after end of the dome supports a sound-absorbing baffle on the forward side of a sound-reflecting pad on the after side. The baffle and reflector eliminate sound reception through the stern section of the dome. The baffle also reduces sound reflections within the dome.

Figure 149 is an illustration of the baffle. The forward side of the baffle absorbs sound sent out by the transducer. The after side of the baffle reflects sound waves that are heading toward the transducer. When a transducer unit is equipped with a baffle, it is useless for you to echo-range toward the stern of your ship—you will hear no sound there.

MOST FIXED DOMES also have a baffle. The fixed dome is likely to be installed on DD's, AVD's, APD's, and CL's. It is straight sided and extends about 4 feet below the keel. The transducer for scanning sonar is retractable within a fixed dome; generally it is allowed to remain lowered when not in use.

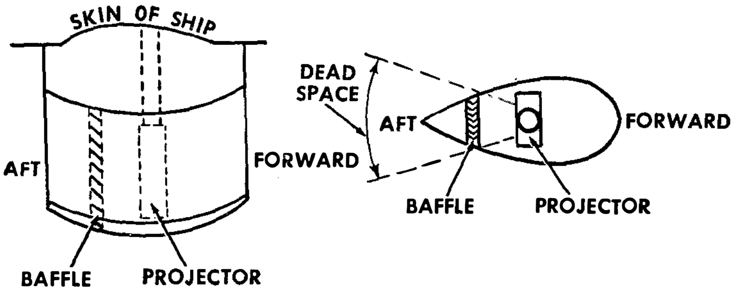


Figure 149.—Searchlight transducers rotate inside the dome.

ATTACK AIDS

There are certain attack aids designed so that the attack team can furnish the conning officer better information. You should have a general knowledge of two of these: The bearing deviation indicator, popularly known as the b. d. i., and the attack plotter, known as the a. p.

The b. d. i., used with searchlight gear, was originally a unit mounted to the left of the stack. It is now a part of the searchlight console model, and is incorporated in the console panel.

The primary purpose of the b. d. i. is to enable the operator to get accurate bearings faster by helping the operator to remain on CENTER BEARING. Study the illustration in figure 150. Pictured here is the face of a cathode-ray tube. Every time a signal is sent out, a spot of light appears at the bottom of this scope and sweeps up to the top at a steady speed, leaving a faint line of light behind it. This light rapidly fades. When the spot of light is near the top of the scope, it is time for the next ping and the spot instantly disappears at the top, to reappear at the bottom of the scope and begin its upward movement again.

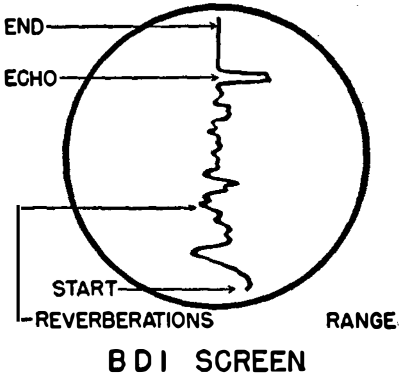


Figure 150.—Bearing deviation indicator scope.

The spot of light will move up the center of the scope in a fairly straight line if there are no echoes. But when an echo comes in, it pushes the spot of light to the right or left, as illustrated in figure 150. The large deflections at the bottom of the scope are caused by the loud reverberations at short range. The other deflection is from an echo. THE DEFLECTION POINTS TO THE DIRECTION THE OPERATOR MUST TRAIN IN ORDER TO REACH CENTER BEARING. When the beam is on center bearing, the deflection is split equally to right and left.

The principle of the b. d. i. is also used with depth-determining equipment. In this case, the deflection tells the operator whether the transducer must be elevated or depressed to get on center bearing.

The ATTACK PLOTTER gives you a visual presentation (on a cathode-ray screen), of your own ship's track, the submarine's track, and your sound beam. There is a line of light called the PREDICTOR LINE which provides a range and bearing that can be used for an ahead-thrown attack.

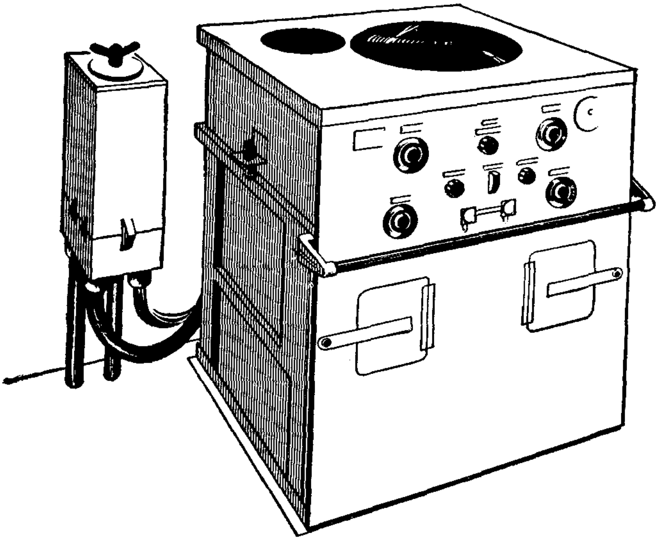


Figure 151.—The attack plotter.

The a. p. is set up so that true north is directly ahead of the operator, east is to the right, and so forth. Courses and bearings come from the gyro and are, therefore, true.

While operating the a. p. you watch the ASW problem develop visually, marking the courses of your ship and the target with a colored pencil. As your ship and the target converge, you switch on the predictor line to determine what course will be needed to lay projectiles in the path of the submarine. If the range of your ahead-thrown projectiles is 250 yards, you set the predictor line to that length (1 inch on the predictor line equals 250 yards of range). The predictor line is trained to a point slightly ahead of the submarine to allow for the sub's travel during flight and sinking time of the projectiles.

At the time of firing, the ship should be steering down the predictor line. If the ship hasn't time to come to that course, then the weapon launchers are trained in that direction so the projectiles will still fall at the proper point on the water.

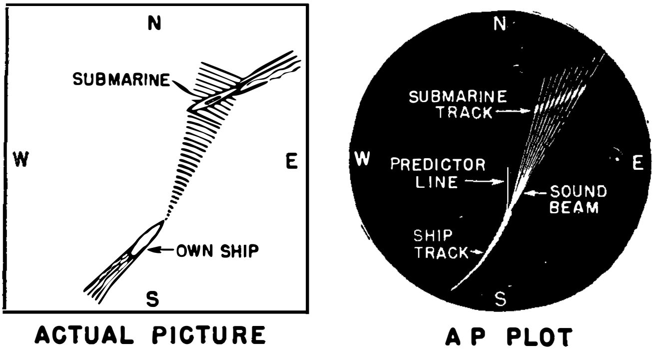


Figure 152.—The picture the attack plotter gives.

As previously stated, the a. p. is an attack aid, and serves as a secondary source of information during an ASW run. It is especially valuable when the recorder fails in the final stages of a run.

PREVENTIVE MAINTENANCE

Cleaning

You can help to keep the sonar gear at the peak of its efficiency by having the equipment clean. An important point to remember along this line is that water and electrical gear don't mix. Don't let water drop on any part of the units, and see that the cables going from one unit to another are not exposed to water.

Check for loose gear or deck plates that may rattle against the deck or bulkhead near the transducer, and lash down all loose gear. Rattling noises near the projector will be heard through the loud speaker and will make it very difficult for you to hear an echo.

Once a week, the inside of the units should be cleaned. Don't attempt to do this until the radio technician is with you and has checked to make sure that all the gear is dead. When you clean the inside of the unit try to get rid of the dust that has accumulated there. The best tool for this is a dry-air blower. A soft brush may be used but the careful not to damage any of the delicate parts of the equipment. DON'T REMOVE ANY OF THE PARTS. LET THE TECHNICIAN DO IT.

Ventilation

The lower sonar room must always be well ventilated. All of the units of equipment located here radiate large amounts of heat as they operate, and unless this heat is taken away by adequate ventilation, the temperature will rise so high that it will damage the equipment. High temperature will cause the driver to shift frequencies radically. It will also cause certain types of train-control to operate poorly.

Lubrication

Proper lubrication is another essential for maintenance of sonar equipment. The best way to learn how to lubricate your equipment is by checking carefully with the instruction books, and then by practicing under the guidance of an experienced operator.

Here are four things to keep in mind before lubricating—

1. Where to lubricate.
2. What type of lubricant to use.
3. How much lubricant to use.
4. When to lubricate.

The instruction books will give you all the information you need.

HOW TO START THE EQUIPMENT

These are the general steps for starting the gear. Learn the exact steps for your particular gear by checking carefully with the manufacturer's instruction book.

1. Turn on the master switch.
2. Press the START button on the local (or remote) control unit.
3. Press the LOWER button on the local (or remote) control unit.
4. Press the START button on the receiver-amplifier.

Set up the receiver-amplifier as follows—

1. Turn on time variable gain (t. v. g.) first or second position for searching.
2. Put meter range on 30.
3. Turn on heterodyne switch.
4. Put the beat frequency oscillator at 800.
5. Have the gain comfortably high.

Set up the range indicator unit as follows—

1. Turn the indicator to AUDIBLE.
2. Make sure the modulator is off.
3. Set the keying interval as ordered.
4. Check the limit switches on the train-control.

HOW TO STOP THE EQUIPMENT

Here's how:

1. Press the stop button on the range indicator unit.
2. Train the projector to 000° relative.
3. Press the hoist button on the local (or remote) control unit.
4. When the green light comes on, press the stop button on the local (or remote) control unit.
5. Turn off the master switch.

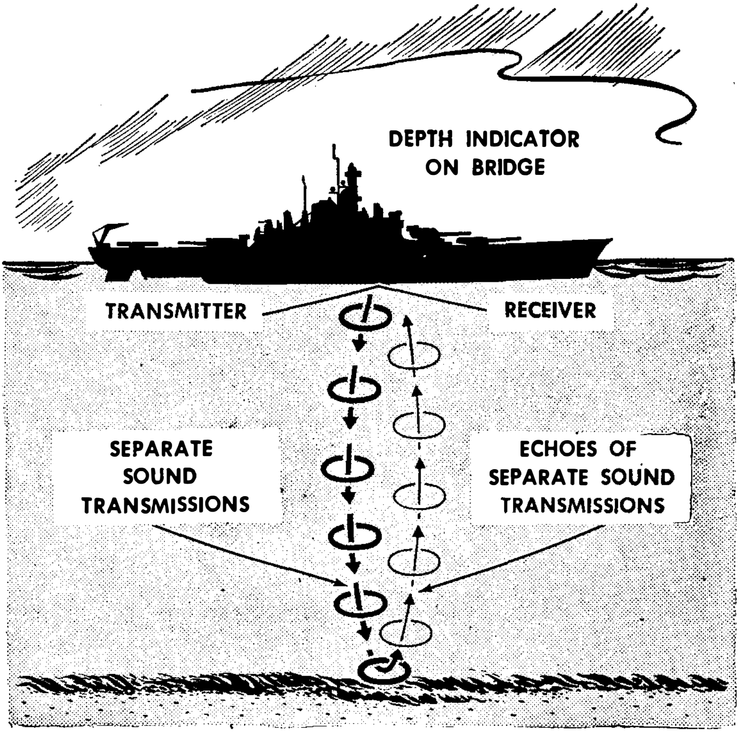


Figure 153.—It's just an echo.

FATHOMETER

Soundings by Echo

Let's consider some basic facts about sound itself, and then you will understand how the FATHOMETER (SONIC DEPTH FINDER) operates. In the first place, the speed of sound is known. It varies only slightly under different conditions. In water, sound travels at about 4,800 feet a second. You know, too, that under proper acoustic conditions, sound bounces back from an obstruction in its path—in other words, you have an echo.

With these two facts in mind, all you need to take a sounding is an instrument with which you can (1) send a sound impulse to the ocean floor, and (2) measure the time that elapses before its echo reaches you. That's exactly what a fathometer does.

Every fathometer has three principal units—a transmitter, a receiver, and a depth indicator. The depth indicator is located on the bridge. Aside from its scale, which gives the soundings at any instant, it has a recorder, which makes a continuous and permanent notation of all soundings received while the instrument is in operation. Figure 154 shows an indicator and recorder housed in a single case, mounted on the bulkhead of a cruiser's chart room.

This is the newer type fathometer. Another model has a circular scale, with the recording mechanism in a separate unit. Both types are in common use throughout the Navy.

The lower line of the scale at the top of the instrument in figure 154 is graduated from 0 to 1,000 fathoms. To get a sounding within this range, you turn the knob marked SELECTOR to shallow, and be sure that the toggle switch marked SIGNAL INTERVAL (lower left) is set at standard.

If you leave the selector knob at shallow and drop the toggle switch to the alternate position, you are adjusting the fathometer for soundings between 100 and 200 fathoms. This is called DOUBLING THE SIGNAL INTERVAL. With such adjustment add 100 to what you see on the scale.

If you are in water deeper than 200 fathoms you must read the upper line of the scale, which is graduated from 0 to 2,000, but first you have to turn the selector knob to DEEP. With the signal interval switch at STANDARD, read exactly what the scale shows. With the switch at alternate, add 2,000 to the reading—800 on the scale would mean a depth of 2,800 fathoms.

You read the scale by noting where the red flashes appear. For every sound signal that is sent to the bottom of the ocean a red flash shows up at the zero mark. At the instant the echo of this signal reaches the receiver, there is another red flash somewhere along the scale. In shallow soundings both flashes seem to occur at the same time, because the echo gets back in a hurry.

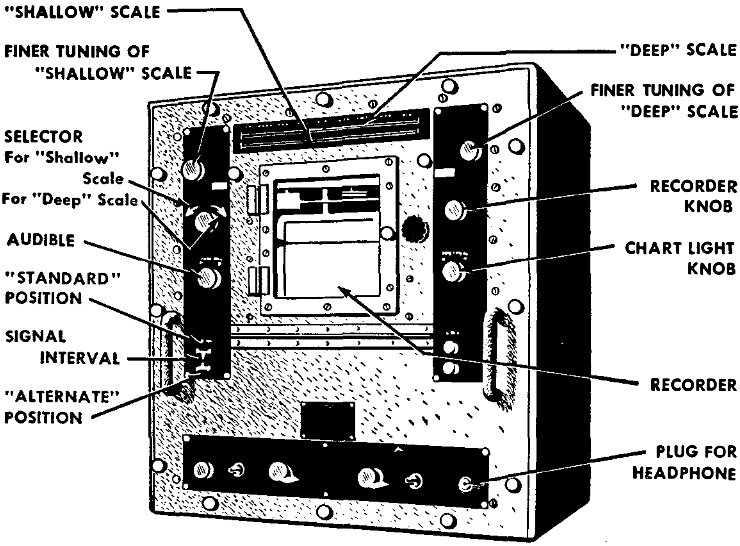


Figure 154.—Fathometer indicator and recorder in a single unit.

The flash of red light is wide enough to cover two gradations on the scale, so read the gradation at the left edge of the flash. Often you see another flash still higher on the scale. Ignore this one— it is the result of a double echo. Remember that you always read the flash showing the smaller figure.

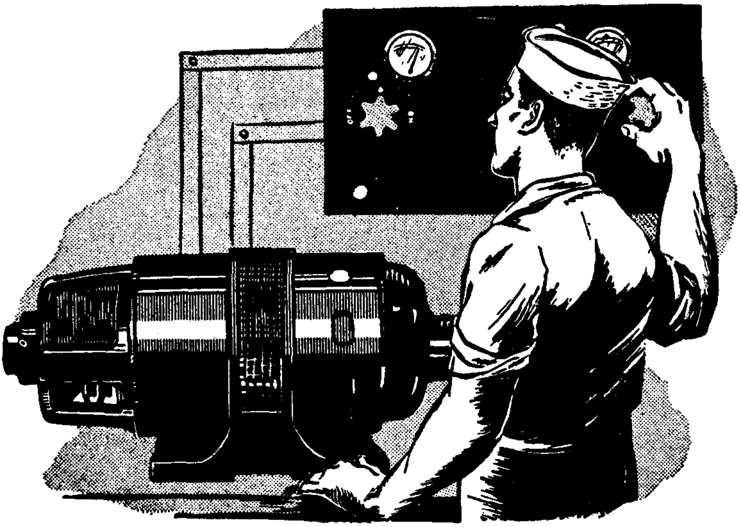
When you have turned the knob marked AUDIBLE to ON, you can hear both the transmitted signal and its echo. It is hard to distinguish between the two in a shallow sounding, but their slightly different PING tones are quite distinct when a deep sounding is being taken.

The knobs marked SIGNAL LENGTH (upper left and right) are for finer tuning, one for use with the shallow scale and one for the deep scale. If the echo is not coming through clearly, or the flashes are faint, increase the signal length.

The permanent record on the chart is helpful for checking your position. To match the slope of the bottom (as shown on your navigational chart) with the rise and fall of the fathometer's soundings often helps you to verify bearings, or even to locate your position when nagivational aids cannot be seen. You won't have any record, however, if you forget to turn on the recorder. Make sure the knob is at the ON position.

QUIZ

1. What is meant by SEARCHLIGHT sonar?
2. With integrated sonar, how is the depth of a submarine determined?
3. What instrument provides the attack course and the time of fire in integrated sonar?
4. Under normal conditions, who conns the antisubmarine attack run?
5. What is the derivation of the term "stack"?
6. What is the function of the transducer?
7. What information does the attack plotter provide?
8. Every fathometer has three principal units. What are they?
9. What is the function of a fathometer recorder?



CHAPTER 11

MOTORS AND GENERATORS

THEY NEED CARE

Have you ever inspected a new motor or generator when it was first installed? Assuming you have, remember how smoothly the parts turned and how easily they worked together? If it were possible to keep a motor in that condition without turning a hand, you'd never have to give it another thought. But, the motor or generator has never been built that doesn't need care.

As soon as a new motor is installed and put into operation, its enemies go to work on it. The first and greatest enemy is friction caused by the metal parts moving against each other. Friction causes heat and wears away the metal. This can be partially overcome by keeping the motor as cool as economical operation will permit, and by forcing lubricating oil between moving parts to reduce wear. The next enemy, dust, is brought into the motor by the air drawn in to cool it. Abrasive dust particles become lodged around moving parts and eventually cause excessive wear. In addition, there are bits of metal that wear off within the motor itself, creating friction whenever they come in contact with moving parts. Finally, there is moisture which causes metal to corrode. Although moisture cannot be completely eliminated at sea, it must be combatted continuously.

The Navy has devised many ways of keeping dust and moisture out of motors, but they still get in and cause damage. To offset this undesirable action, motors are constructed of the best available material, precautions are taken to prevent corrosion, and to see that the equipment is clean and well lubricated at all times.

Remember, best results are obtained from a clean motor. This chapter will show you the value of adequate lubrication, the finer points of maintenance, how to clean thoroughly, and how to inspect for signs of wear or corrosion.

CLEANING

The Navy expects you to go over the motors and generators in your charge at least once a week to inspect, clean, and lubricate them according to Navy standards. When you clean a motor, make sure you're doing a thorough job. Clean it both inside and out, removing all dust and particles of metal. Don't allow dust to collect inside the end windings of the armature, especially in the couplings and commutator ends. An accumulation of dust here may ground the coils and burn them out. Dry compressed air is recommended for blowing dust out of a motor, but don't use a pressure hose since it will force dirt into the motor insulation. A hand bellows is better. The bellows furnishes air at low pressure, and can easily be handled in tight places. Make sure you don't force dirt into the narrow spaces between conducting parts or into air ducts. Wipe the brush holders, studs, and leads; clean the brush holders thoroughly, being careful to remove all carbon dust that has worn off the brushes.

If there is dust and dirt on the coils, remove it with a rag dampened with carbon tetrachloride. Don't get carbon tetrachloride on any steel parts, however, for it combines with moisture and causes the metal to rust. Another thing, don't work in a confined place with carbon tetrachloride since it will evaporate and contaminate the air. Remove all deposits of salt from the gear and rub the spots down with a thin (light grade) oil.

You must also be very careful when you paint a motor or generator. It's a difficult job to paint the inside of field frames and housings without dropping paint on the field coils, leads, and brush riggings. Another thing, you can't just use any paint that might be handy. Many paints, white lead for instance, contain material of a conducting nature. Use only the best grade insulating varnish as prescribed by the Navy.

BRUSHES

Brushes will wear rapidly unless they are properly set, and operating at correct pitch and tension. It's up to you to see that they are correctly staggered so they won't wear grooves in the segments. In figure 155 you see illustrated the correct and incorrect methods for placing brushes on a commutator.

There are a number of precautions you can take to see that your brushes wear evenly. First, check the brushes themselves to see that they move freely and make proper contact with the commutator. They must be staggered in pairs of studs, so arranged that a positive brush will follow one that is negative, thus offsetting the electrolytic effect. Stagger the brushes in pairs of studs in a 4- or 8-pole motor. If you have a 6-pole motor, however, you'll have to stagger four of the six studs in pairs, and then break joints with the two remaining studs. It's advisable to inspect the brush faces to see that particles of copper are not imbedded there to cause excessive sparking. At the same time, assure yourself that the brush tension is correct.

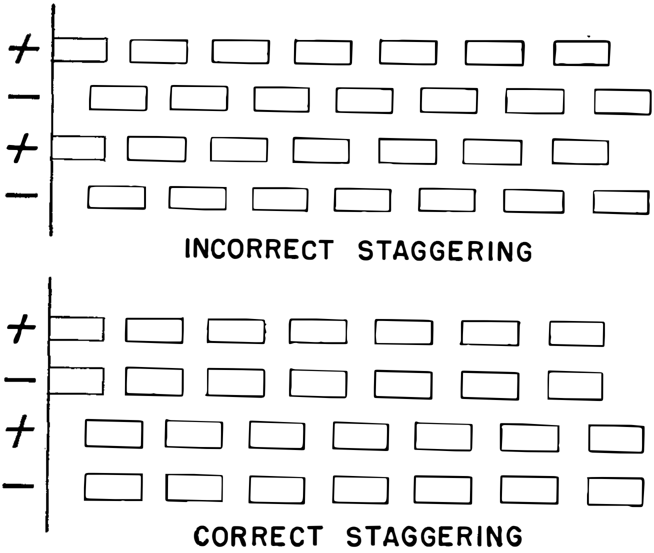


Figure 155.—Correct and incorrect stagger of brushes.

COMMUTATOR

The commutator must always be in excellent running condition if you expect to receive top performance from your motor. The surface of the commutator should be highly polished and uniform in shade. Blackening of groups of bars at regular intervals is evidence of poor adjustment of the bars, incorrect brush position, or poor contacts. If the spots are located at regular intervals it may be caused by a commutator that is rough or is not a true cylinder. Normally, a commutator doesn't need much cleaning. With each inspection of the motor, simply wipe the commutator with a piece of dry canvas. The slots in the commutator will have to be cleaned occasionally to keep the mica well below the wearing surface and to remove any fins or slivers that may be sticking out.

Leave your oil can in the locker when you work on a commutator—it doesn't use any. Lubricants have the bad habit of working into the side mica of the commutator and destroying the insulation. This causes short circuits between the segments.

The collector rings of motors using brushes of a metallic composition run at a higher temperature than commutator brushes and DO need a little oil now and then. Apply this oil with a small soft brush, using just enough to lubricate the collector ring brushes; wipe off all excess oil.

Occasionally you will find it necessary to smooth a commutator. The exact method to use depends upon the amount of roughening which has occurred. If very little smoothing is required, you can go over it with fine sandpaper. (Never use emery cloth for particles of emery dust may lodge in the gaps between segments. These are conductive and will cause short-circuiting.) First fit the sandpaper into a wooden block made to the shape of the armature curve. Hold it firmly against the surface to be sanded, drawing it in the direction of rotation of the armature.

The quickest way to smooth a very rough commutator or collector ring is to grind it at full speed using a commutator grinder. The grinder will do a much better job than a lathe. The best results are obtained with a number of light passes rather than steady grinding. If you hurry the job, or crowd the grinding wheel, the finished commutator may come up unsymmetrical. While grinding, be sure to keep copper dust away from other parts of the motor. The field coils should be protected by a stationary guard and the armature fitted with a tight canvas head securely bound over the ends of the commutator or armature. Stuff the ventilating space and be

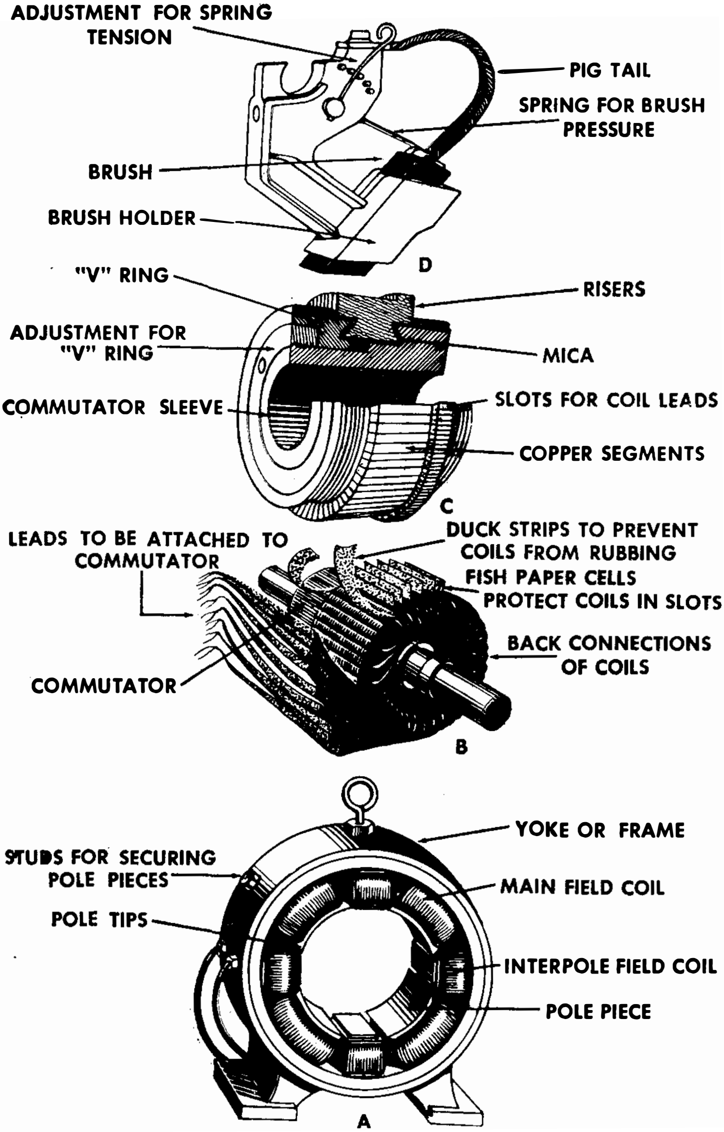


Figure 156.—Parts of a generator.

careful to remove all dust with the stuffing when you are through grinding.

When a single bar of a commutator is out of line with the cylindrical surface, it will cause the brushes to vibrate, resulting in poor contact and sparking. Tap such a bar back into place with a wooden block and a mallet. When you find a low bar, check for a slackening of the commutator end bolts. It may be necessary to readjust the entire commutator.

As the copper wears down, the mica may become exposed, causing vibration or sparking. Sandpaper won't cut the mica so you'll either have to use a lathe, grinder, or some sharp cutting instrument. You can save yourself a lot of trouble by undercutting the mica when you turn the commutator. Use a wooden stick to remove dust from the gaps between segments.

CLEANING WINDINGS

The use of compressed air is the most effective way of cleaning windings. Since you want the pressure to be low and the air dry, a hand bellows will once again serve nicely. A compressed air-jet usually contains moisture and there is always the added risk of forcing dirt and grit into the windings. The main concern in cleaning windings is to remove the metallic dust which has accumulated between the commutator segments.

End-windings require thorough cleaning and overhaul once a year. When the end-windings are cleaned, apply a coat of air-drying varnish, evenly distributed so the air passages won't be clogged. Be sure to check the varnish too thick for use. The usual thinners are benzine or spirits of turpentine. If the label shows a different thinner was used, you'll have to use that particular kind when you thin the varnish. It's advisable to have the varnish and thinner at about 86° F. before you mix them, adding a little thinner at a time and stirring constantly until you reach the consistency you desire. A thin, well-mixed varnish can be sprayed, though you must be very careful to avoid spraying it into electrical contact surfaces where it will insulate and cut off the current. It's a good idea to remove all the brushes and wrap the commutator ends with canvas before you commence varnishing.

OVERHEATED BEARINGS

The two greatest causes of heated bearings are improper cleaning and inadequate lubrication. These two basic causes usually lead you to others—gummed bearings, scratched or corroded journals and sometimes, poor insulation. Overload may also account for heating, but this can be avoided by carefully watching your readings.

Dirt will sometimes clog a gage glass, giving an indication of oil when none is present. Oil rings often wear out of round and fail to rotate properly; the lack of end-play on the shafts will cause binding. A bent shaft will cause a motor to vibrate and grind at the journals, the trouble increasing as the shaft heats and expands.

Pay particular attention to a piece of equipment that isn't running properly, and if you must keep it in operation, there are certain precautions to take. Overheating can be reduced by a liberal supply of fresh oil, and in extreme emergencies, the motor can be cooled with water. Remember to keep oil and water away from electrical contacts. Proper inspection and maintenance will locate trouble before it happens, giving you time to make repairs or clean the equipment as necessary.

CLEANING BEARINGS

During a regular overhaul of a motor or generator it's a good idea to flush the bearings with hot mineral oil or carbon tetrachloride. Carbon tetrachloride is preferable in that it dissolves grease more readily than oil and it doesn't have to be heated. Remember to remove all carbon tetrachloride when you are through flushing.

The first step in cleaning bearings is to clean around the filler fitting and relief plug. Remove the caps, and take out any accumulations of hardened grease. With the machine running, inject solvent with a syringe through the filler hole. As the grease becomes thin it will drain through the relief hole. Continue adding solvent until it drains reasonably clear, then replace the relief plug and inject a small amount of solvent. Allow it to churn for a few minutes, drain, and repeat, if necessary, until clear. Refill with new grease.

When carbon tetrachloride has been used as a solvent, the relief plug should be replaced after cleaning and a small amount of light lubricating oil injected. Allow this to churn in order to flush the carbon tetrachloride.

LUBRICATION

The life of any motor or generator depends to a great extent upon the lubrication it receives. Oil and grease wear out and new lubricants must be added when necessary. Light thin oil that is forced into a rapidly moving part won't last as long as the heavy grease used to lubricate a slowly moving gear. This fact makes it essential that you inspect some parts more often than others, and here's where your Navy lubrication charts come in handy. The Navy, through its various manufacturers, furnishes lubrication charts for all its equipment. These charts show how often certain parts require lubrication under particular operating conditions, and tells you the amount and type of lubricant to use. Lubrication charts are the result of years of research and experiment and should be followed as closely as possible.

Adequate lubrication is a necessity, but here as elsewhere, you can overdo a good thing. Too much oil is almost as bad as not enough. Excess grease will cake up, gather dust, and hinder efficient operation. A thick covering of grease, oil, and dust will cause a motor to heat, making it a fire hazard. When oil cups are allowed to run over the oil will drip into the brush riggings and field coils where it often seeps into the commutator windings and causes real trouble. Under normal conditions a high grade lubricant will last about 60 days, but you must inspect operating equipment daily to make sure it is receiving adequate lubrication.

A heavy lubricant cannot reach a small, rapidly moving part and a light oil will flow past a heavy, slow moving gear. In cold weather a heavy oil will become too thick to flow and a lighter grade must be substituted. In hot weather a thin oil will become thinner and lose much of its lubricating power.

Oil wells that furnish lubrication to the more rapidly moving parts should be filled to the level of the filling vent with a 2250 lubricant or its equivalent. Grease cups generally take a mineral lubricant of Navy specification 14G13 or some similar type. After a grease cup has been filled, all you have to do is turn the cap to force additional grease into a moving part. Turn the cap one full turn daily when motors are in continuous operation. For the heavier equipment, use Navy medium B alemite lubricant, such as Marfak No. 3, keeping the housing from one-third to two-thirds full.

A few motors and generators have a regular pressure relief lubrication system that makes the lubricating job a lot easier. You don't have to disassemble a motor to check the amount of grease in the housing, and grease doesn't have to be removed since it is forced out of the housing as the new grease is put in. Routine greasing doesn't interfere with normal operation and overgreasing is prevented. There is one thing you must remember about pressure relief lubrication. Always remove the relief plug before additional grease is forced in or the extra pressure may force grease along the shaft into the commutator.

There are no "best" motors or generators, but some are better suited to perform certain jobs than others. They may require different types of lubrication, but basically they all operate on the same principle. All generators deserve the same amount of care and lubrication, and if maintained according to their individual needs, will provide the maximum in operating efficiency.

INSPECTIONS

Careful inspection will do much toward eliminating your motor and generator troubles before they begin. It is necessary that specific inspection periods be set up and that all necessary precautions are taken to insure proper maintenance. Routine inspections are established according to the needs of a particular motor, but general inspections are divided into daily, weekly, quarterly, and semiannual inspections.

DAILY—Examine each motor-generator thoroughly and note the condition of the commutator, oil cups, rings, and bearing temperature. Check for the presence of dust and other foreign particles in the motor.

WEEKLY—Operate each idle motor-generator for at least 30 minutes, checking its operation and making sure that no troubles have developed that would impair its efficiency.

Inspect each unit for sparking at the brushes; see that the commutator is clean and that the brushes are properly adjusted and running smoothly. Check the brush pressure and clean brush rigging, but don't allow dust to fall into other parts of the motor. Check the starting panels and see that they are clean.

QUARTERLY—Go over the lubrication points of the motor, checking with the lubrication chart to make sure you don't pass up any important points. Drain oil wells and flush with kerosene. Blow each unit with dry compressed air, using a hand bellows. Dust off brush rigging and remove any dust lodged between conductors or commutator bars.

SEMMIANNUALLY—Check insulation for evidence of wear or breaks. Examine the commutators of all spare armatures, giving each a quarter turn to prevent sagging.

ARMATURES

The greatest possible care should be exercised when handling an armature. Wrap the armature and commutator assembly with canvas before you lift them out of a motor. Prior to setting them down, be sure you have a place ready where they may be set without damage. Use a soft pad made from a thickly folded tarpaulin to set the armature on, or rest the shaft ends on a block or

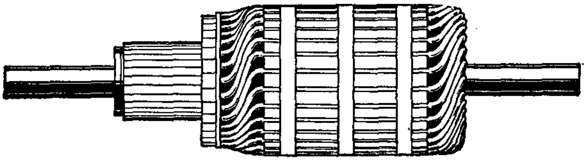


Figure 157.—Generator armature.

trestle. Be sure to use spreaders on the lifting slings so the line won't press against the armature and cause damage to its vital parts. When the armature is ready to clear the frame, make sure no pieces of steel, bolts, or fittings, are still attached to the machine. Carefully examine both armature and frame before replacing them in the motor.

REMOVING A POLE

When you remove a pole it is not necessary to remove the armature. All you have to do is disconnect the field windings and remove the bolts that secure the pole to the frame. Then slide the pole out with the windings. When you are ready to replace the pole be sure to use the same number of liners under it as you found there when you took it out. Use only the high permeability sheet iron liners which were originally under the pole. After you set up the pole, check the air-gap measurements. When a spare pole is installed, a different number of liners may be required to make it level and secure.

THE YOKE

If it becomes necessary for you to remove a brush yoke, be sure to mark the yoke, the casing into which it fits, and all connections, so they can be replaced in their original positions. The proper position of the yoke is determined when the generator or motor is tested at the factory, and should be plainly marked. These marks normally correspond to the full-load position, though motors and generators are frequently operated at less than full load. When this is the case it may be necessary to shift the position of the brushes slightly to secure the best commutation.

INSPECTION FOLLOWING MOTOR ASSEMBLY

When a motor has been assembled and is ready for operation, it must be closely inspected to make sure it is ready to do a good job. Make sure the operator knows what has been done to the motor and that he understands the machine's instruction book. The voltage name plate data of the unit should be checked with the power supply circuit to make sure they correspond. Also be sure the blueprint furnished conforms with the internal circuit of the motor.

Go over the motor in detail to see that all is ready for operation. Make a final inspection to determine that no bolts, nuts, or other spare parts have been left where they can do damage. Check the armature to be sure all segments are evenly spaced; give the armature a couple of turns to make sure it rotates smoothly. Check the poles to see that they are matched with the center of the armature core. Look over the brushes, making sure they are free, have the correct tension, and fit on the commutator. Check for suitable clearances to prevent arcs and make sure the main field air gaps are wide enough, and true, over the entire surface. Then check the starting panel and turn on the motor, checking the load it is carrying. Inspect it to make sure it is running smoothly, and that there in an absence of sparking or high temperature. If there is evidence of heating you should stop the motor and inspect the insulation, the commutator, the leads, and the armature itself.

INSULATION HIGH POTENTIAL TESTS

It is advisable to put all a. c. and d. c. motors through a high potential test before placing them in operation. Use one-minute charges of alternating current for this test, varying the voltage to suit a particular motor and the type of insulation with which it is fitted. Standard practice requires a test that is double the working voltage plus 1,000. This does not apply where 1,500 volts is the minimum value.

Rebulit or repaired a. c. or d. c. units should not be subjected to more than one-half the values given above since the insulation may be old and unable to take a greater charge. The best insulation test for old motors is a voltmeter used in series with the power circuit. This test will indicate a weakening of insulation without using the high potential test which may break down old insulation. Never put a high potential test on a motor unless it is clean and thoroughly dry.

TESTING CABLES AND WIRING

To make sure all cables and wiring receive a test each year the various circuits are divided into convenient groups, each to be inspected during a certain periodic maintenance inspection. The first step on any inspection is to deenergize and isolate all power and lighting circuits. You then test the insulation resistance between each conductor and ground, and between conductors of opposite polarity in the same cable, using a megger.

The minimum safe value of insulation resistance depends on the total length of the cable and the nature of the apparatus included in the circuit tested. There are so many circuits in the average machine that no attempt will be made to give you any minimum values. You should, however, keep a record of the resistance on each circuit, and the next time you inspect that circuit you'll have your record as a check. If any marked reduction in the value of resistance is obtained, as compared to previous checks, it will be necessary to go over the circuit cables and connecting equipment in detail.

SHIPMENT OR STORAGE

When an armature is to be packed for shipment or is to be stowed for a period of time, there are certain precautions that must be taken in preparing it for safe-keeping.

The first step is to clean the armature shaft with sodium bicarbonate solution and give it a coat of spar varnish. Follow this with a coat of white lead and tallow. The windings and commutator should be wrapped in oil-paper covered with oilcloth, this cover extending over the ends of the armature and lashed to the shaft.

The best packing case is one made of galvanized iron, divided into two parts, that can be fitted over the windings and the commutator. The joints of this case should join in such a way that they can be soldered together to keep out dust and moisture.

After packing the armature in the iron case, a wooden frame is built around it to absorb shocks and make it easier to handle. The type of crating used will depend on the size of the armature.

For purposes of identification the serial number of the armature, type of motor and other pertinent data are stenciled on the packing case in two or more places. This information should also be stenciled on the iron covering case.

The metal cases of armatures stowed aboard ship should be opened about every 4 months and the armature inspected to make certain it is being properly preserved. After the armatures are inspected, the metal cases will have to be resoldered. Make sure this resoldering is done in a dry atmosphere by competent personnel and that the completed job is thoroughly inspected.

MOTOR-STARTING PANELS

When you start a motor that is controlled by an automatic contactor panel, be sure all starting resistance has been cut out beforehand. If an accelerating contactor fails to close, the condition will probably be indicated by the failure of the motor to build up to its normal speed. Failure of one of these contactors will leave some starting resistance in the armature circuit and if not removed, will soon overheat and burn out some part of the armature.

Protective devices on panels are installed to prevent overload and shorts that may injure a motor and necessitate expensive overhaul. These devices are essential to safe motor operation and should be inspected and tested frequently. When you go over the protective devices it is a good idea to check the operation and sequence of the contactors, since the failure of one contactor may disable the entire panel. Keep the flexible connector terminals tight; check for open circuits. See that flame deflectors are properly placed to prevent a spreading arc and keep inflammable substances out of the panel. Keep the panel clean and dry, and lubricate sparingly. When panels not in use are equipped with doors or covers, keep these doors and covers closed. When dust and moisture are kept out, the necessity of repairs will be reduced.

It is advisable to keep the spring on the starting rheostat arm strong enough to throw the lever to an OFF position in case of current failure. The contact buttons should be tight and of uniform height; the sliding contacts should be smooth and bear evenly on the contact buttons. The overload and no-voltage pins, the starting lever shaft, and solenoid contact blocks should be dismounted occasionally and cleaned with very fine sandpaper. Contacts that are kept bright and free from dust or paint, will operate with little danger of sticking.

CIRCUIT BREAKERS

Go over circuit breakers and contactors frequently to make sure the contacts are in good condition and that all connections are tight. If a contact is burned it should be smoothed down with a file or renewed if necessary. Laminated brushes should be lubricated with a light film of vaseline, and hinge pins should be given a few drops of medium-weight oil. Don't lubricate the copper or carbon arc-rupturing contacts. Have levers working smoothly as they may stick and keep a breaker from opening. Check circuit breakers to make sure they will break the circuit at the limiting current for which they are set.

RHEOSTATS

Rheostats are more likely to short-circuit than any other panel accessory, so you'll have to give them a little extra attention. In addition to keeping them dry and free from dust, all exposed surfaces should be wiped frequently to keep down surface leakage. When these surfaces crack, they should be renewed. If the rheostat gets wet it must be thoroughly dried before being put back in operation. The drying process can be speeded up by passing a low current through the rheostat, keeping it warm until all moisture has been expelled. When the rheostat is dry the insulation-resistance reading will be about one megohm or better.

SWITCHES AND FUSES

Keep all switch clips smooth and tight to insure good contacts. Switches are designed to give a much lower value of amperes per cross section than are the cables that enter or leave them. However, switch value will rise rapidly when the clips are loose or the contact areas are rough.

Fuses can be a source of trouble when they are not used or replaced correctly. A fuse should have a carrying capacity about one-third higher than the normal current it is designed to protect. If you are using renewable fuses, the fusible element should be installed in a shop where the light is good and other facilities are available to insure tight, adequate contacts. Unless an immediate emergency exists, the blowing of a fuse should always be investigated to find the cause of the current overload. Never use fuses of a higher capacity than the one replaced, and avoid increasing the circuit breaker setting without first inspecting the defective circuit.

PANEL CLEANING

Panel-type controllers should be cleaned frequently with a painter's brush. If some particles won't brush off, you'll have to remove them with a flannel rag or chamois skin, making sure no lint is left in the connections. If moisture is present, it should be removed with a cloth. The panel must be baked if the moisture is excessive. Remember that surface moisture acts as a conductor and its presence will often account for low-circuit insulation-resistance readings.

Since you must go over the panel to clean it, it is advisable to take care of your periodic inspections at the same time. Tests are divided into the following periods:

DAILY—Check each control appliance actually in use by checking a few cycles of its operation to make sure it is functioning satisfactorily.

QUARTERLY—Go into the back of the panel and check those spots that are hard to reach. If the panel is clean, shows no local heat, and the insulation resistance is good, it should not be dismounted if operating satisfactorily.

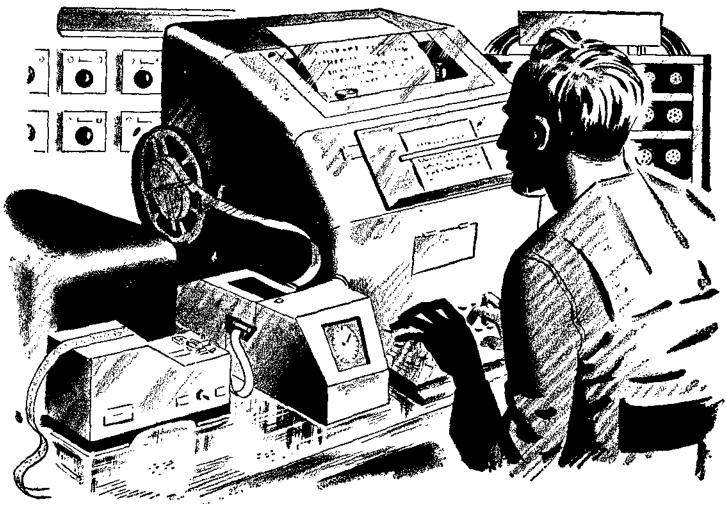
If these conditions are not met, however, the panel should be pulled down to correct the defect.

ANNUALLY—Shut off all power on the main power and distribution boards. Give each a thorough examination for chafing, loose nuts and connections, and breaks in insulation. Blow out dust and dirt and make an entry of your inspection in the machinery history.

When you work with motors, generators, or their starting panels always be sure to keep all protective devices in good working order and at their designed settings. Covers for all parts of the machine or its control panel should remain closed; all gaskets must be in good condition and free from paint. In the end, the longevity of your motor or generator is a matter depending on your own common sense. It stands a good chance of a long life if you operate it sensibly, lubricate it properly, and KEEP IT CLEAN.

QUIZ

1. Why should slotted commutators have their slots cleaned out?
2. What color is the commutator when it is in a normal operating condition?
3. What should be done when contacts are burned?
4. How may grounded coils be detected?
5. What causes a bright spark to appear under one brush and gradually cut a groove in the commutator?
6. What is a good way to clean the commutator? What should be kept in mind while cleaning?
7. Why should sparking at the brushes be promptly remedied?
8. When can fuses be considered a source of trouble?
9. Why should switch clips be kept smooth and tight?



CHAPTER 12

TELETYPEWRITER EQUIPMENT

FAST AND RELIABLE

You've been in Navy communications long enough to know that the tools of your trade are constantly changing. New procedures replace old; new and better equipment is developed. Each change has but one aim—to move military information faster and with greater reliability.

How do these changes affect you, as a leading PO in the radio gang? If it's a change in procedure, you have to give your operators the word and see that they make use of it. If you get new equipment, you must learn how to install, operate and maintain the gear, and be prepared to supervise your men in the same duties.

Although the teletypewriter has been in use by the Navy for some time, it's still a comparatively new equipment. Increasing use of this equipment—especially the radioteletypewriter (RATT)—has meant added responsibilities for every Navy Radioman. The purpose of this chapter is to introduce you to some of the basic teletypewriter duties of the RM1 and C.

THE MODEL 19 SET

The workhorse of teletypewriter communications is the MODEL 19 SET. It is used for both radio and landwire messages. As a matter of fact, you'll fiind components of this set incorporated in almost every combination of teletypewriter sending and receiving equipment. For an all-around communication "package" unit, it's hard to beat. The operator has at his fingertips a switching arrangement which gives him either direct keyboard transmission, tape perforation, or simultaneous direct keyboard transmission AND tape perforation. The two components which make the model 19 so flexible are the model 15 page printer and the model 14 transmitter-distributor. These are mounted on a metal table which provides a slip connection base for quick removal and installation of the T–D; switching key and electrical receptacles which are wired for convenient connection to power sources and the signal line.

When a model 14 reperforator is used, it is mounted on an auxiliary table to the left of the basic equipment. To provide for the reperforator, the model 19 table includes electrical receptacles and wiring for the power, local direct current and signal circuits of the reperforator. There is also a control button for feeding blank tape out of the reperforator.

The model 19 table has a shelf on which a rectifier is mounted, either an REC–13 or REC–30. The rectifier supplies direct current for perforating magnets, line relay biasing windings, and local circuits of the printer (and reperforator, if used). It also adjusts motor power voltages to correct values. The REC–13 is a dry-disk type and the REC–30 uses vacuum tubes.

Figure 158.—The model 19 set.

The model 19 set may be equipped with either a series-governed motor or a synchronous motor. At the present time, the synchronous motor is coming in for greater use, and may, at some future time replace the series-governed motor for use in teletypewriter equipment. There are two reasons for the change. The governed motor requires more maintenance than the synchronous, and, at most teletypewriter stations, a steady 60-cycle

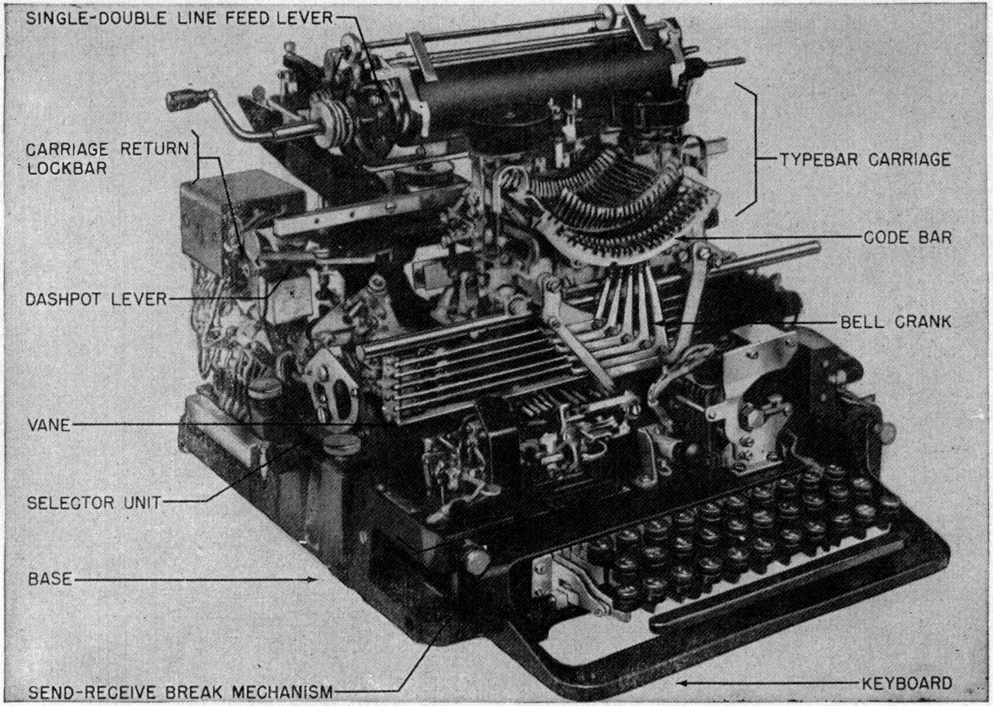


Figure 159.—The model 15 page printer, cover removed.

Restricted

current is available which makes the synchronous motor adequate for the job.

Incidentally, you can expect to find a number of off-make motors in use by the Navy. This is the result of a serious motor shortage during the latter part of World War II. As these motors wear out, they are being surveyed and replaced by standard motors manufactured by the Teletype Corporation.

Up to this point you have had a light "once-over" of equipment with which you should already be familiar. If you have not recently been assigned teletypewriter communication duties, a review of the *Radioman 3 and 2* training course will refresh your knowledge of operation and procedure.

MODEL 15 PAGE PRINTER

The teletypewriter model 15 type bar page printer (figure 159) is a motor-driven mechanism for interchanging typewritten messages between two or more points connected by wire or radio. When the model 15 is used as a sending-receiving station it is equipped with keyboard transmitting unit (fig. 183), a typing unit (fig. 162), and a motor unit, all mounted on a base unit (fig. 164).

Only a brief discussion of the mechanical functions of the model 15 can be included here. To trace the action of numerous moving parts involved in printing a message requires the use of equipment instruction books. In the

UPPER CASE	WEATHER SYMBOLS	↑	⊕	○	↗	3	→	↘	↓	8	↙	←	↖	.	⦷	9	0	1	4	'	5	7	⦶	2	/	6	+						
	COMMUNICATIONS	–	?	:	$	3	!	&	£	8	'	(	)	.	,	9	0	1	4	'	5	7	;	2	/	6	"						
LOWER CASE		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	BLANK	C.R.	L.F.	SPACE	LTR. SHIFT	FIG. SHIFT
	1	●	●		●	●	●				●	●						●		●		●		●	●	●	●					●	●
	2	●		●				●		●	●	●	●				●	●	●			●	●	●						●		●	●
	FEED HOLES	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
	3			●			●		●	●		●		●	●		●	●		●		●	●		●	●					●	●	
	4		●	●	●		●	●			●	●		●	●	●			●				●		●				●			●	●
	5		●					●	●				●	●		●	●	●			●		●	●	●	●	●					●	●

Figure 160.—Teletypewriter keyboard symbols and code.

instruction book you'll find all the details, plus complete instructions for cleaning, lubricating and adjusting the machine.

SIGNALING CODE

Before discussing the various components of the model 15 printer, let's look at the code which carries intelligence between teletypewriter stations. Teletypewriters use an electrical code of current and no-current. Impulses which energize the selector magnets are known as MARKING (current), and those which do not energize the selector magnets are known as SPACING (no-current). Each character transmitted is assigned a code of five impulses, hence the designation "five-unit" code. The LETTERS key, for instance, is transmitted as five marking (current) impulses, and the BLANK key is transmitted as five spacing (no-current) impulses. All other characters have been assigned different COMBINATIONS of marking and spacing impulses.

Before a character is transmitted it is first preceded by a START impulse (no-current). Immediately upon transmission of the five-unit code, a STOP impulse (current) is transmitted. The purpose of the start and stop impulses is to maintain synchronism between sending and receiving machines. These impulses precede and follow each code group, but have no bearing on the intelligence which is being transmitted.

KEYBOARD TRANSMITTING UNIT

The keyboard transmitting unit is, essentially, a set of keys, key levers, selector bars, and locking levers. Their function is to SELECT the code combination to be transmitted when the operator depresses his key. A transmitting cam cylinder, contact levers and contact springs then transmit the code combination which is selected (fig. 165). A clutch throw-out lever and a clutch (figure 166) are provided for starting and stopping transmission.

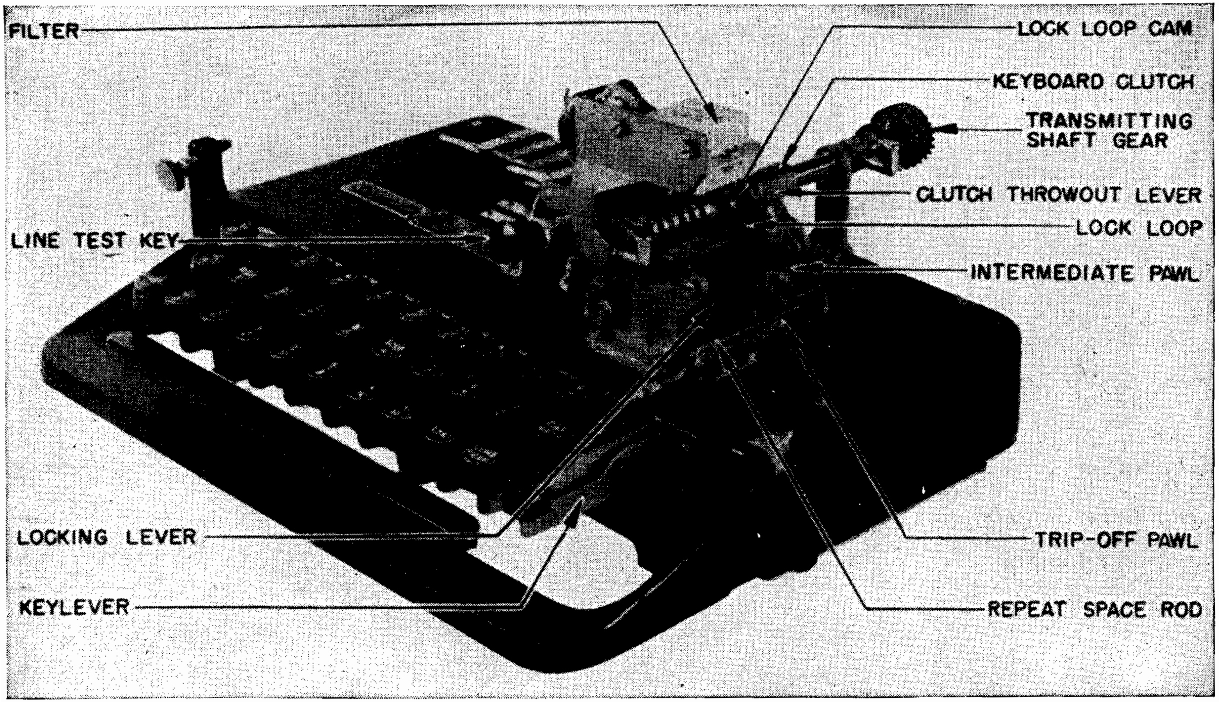


Figure 161.—Model 15 keyboard transmitting unit.

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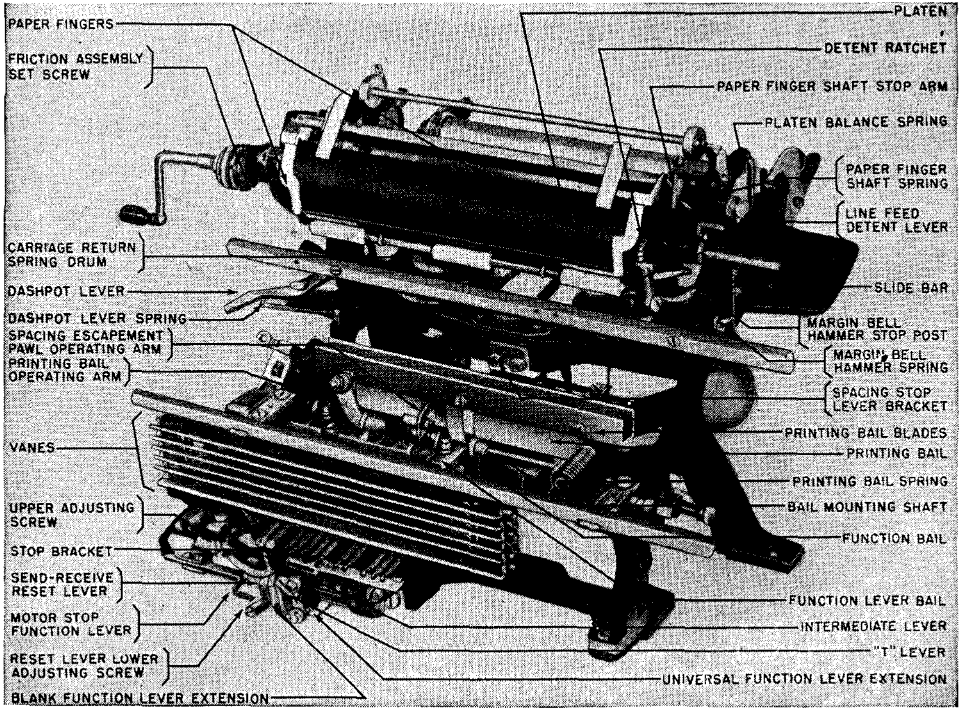

Figure 162.—Model 15 typing unit, front view.

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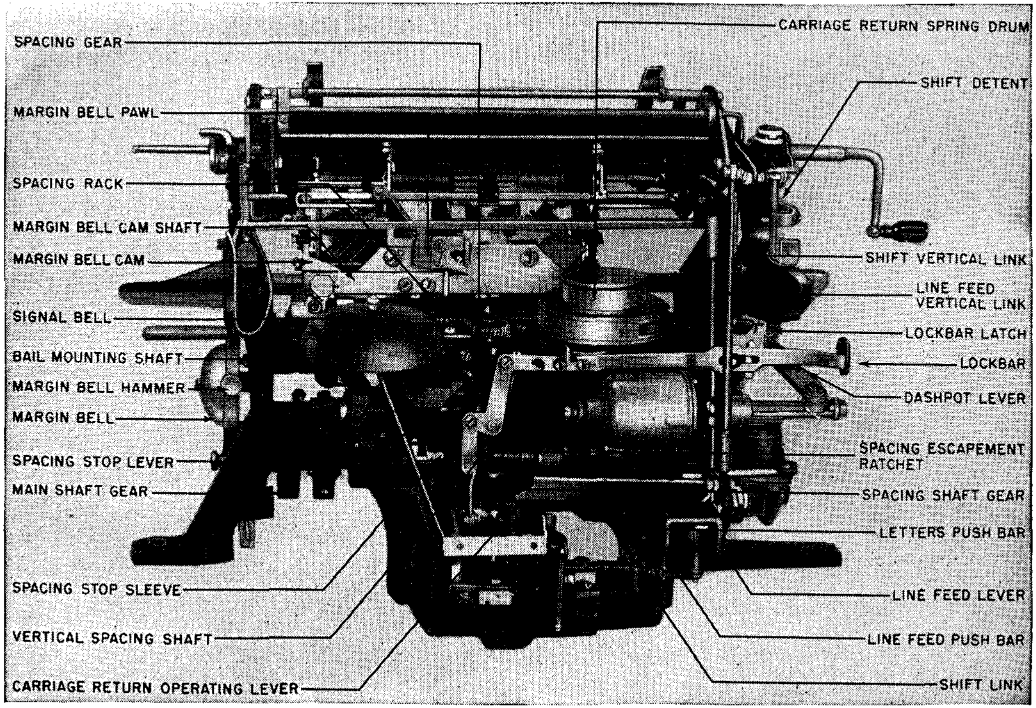


Figure 163.—Model 15 typing unit, rear view.

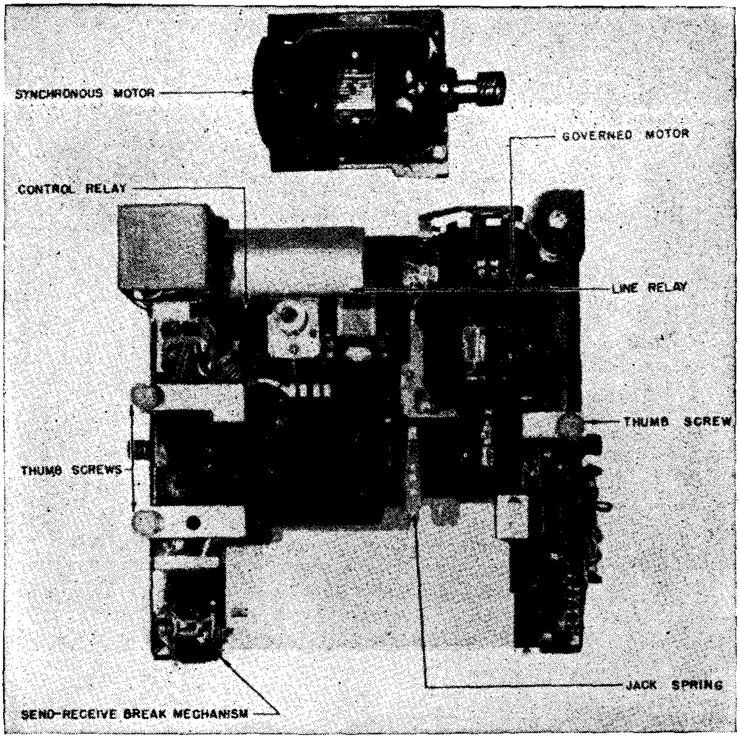


Figure 164.—Base unit and motor.

Beneath the key levers are five selector bars and a universal bar extending across the width of the keyboard. (This is shown in fig. 166.) The selector bars are made with saw-tooth shaped notches, according to the requirements of the signaling code. They rest on rollers and are guided at each end so that they are easily moved endwise. When a key is depressed, the key lever strikes the slanting sides of these notches, moving the bars either to the right or left, depending on whether the impulses corresponding to the bars are to be SPACING or MARKING impulses. In this way the correct code is selected for transmission, and the character starts on its way to the receiving machine.

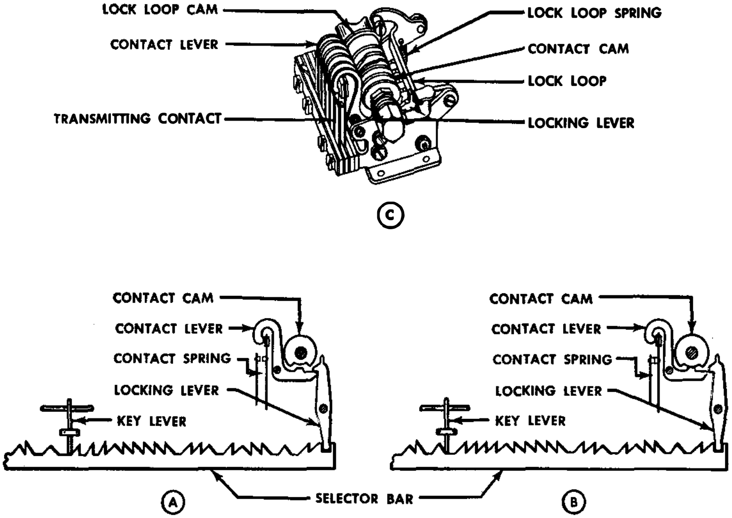


Figure 165.—Transmitting cam cylinder, contact levers and springs.

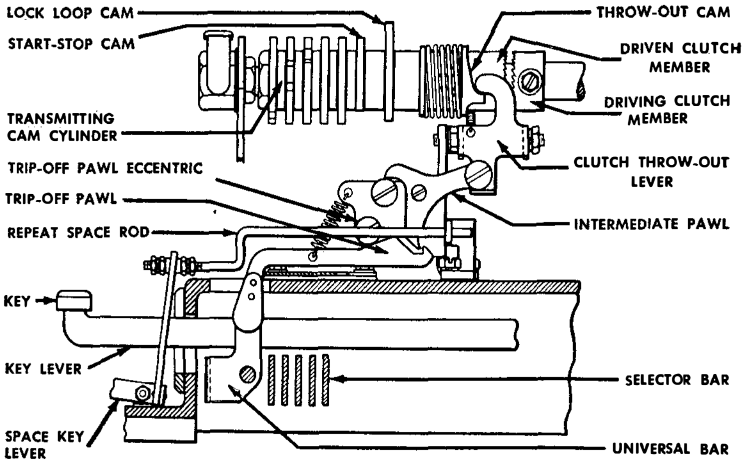


Figure 166.—Transmitting cam cylinder.

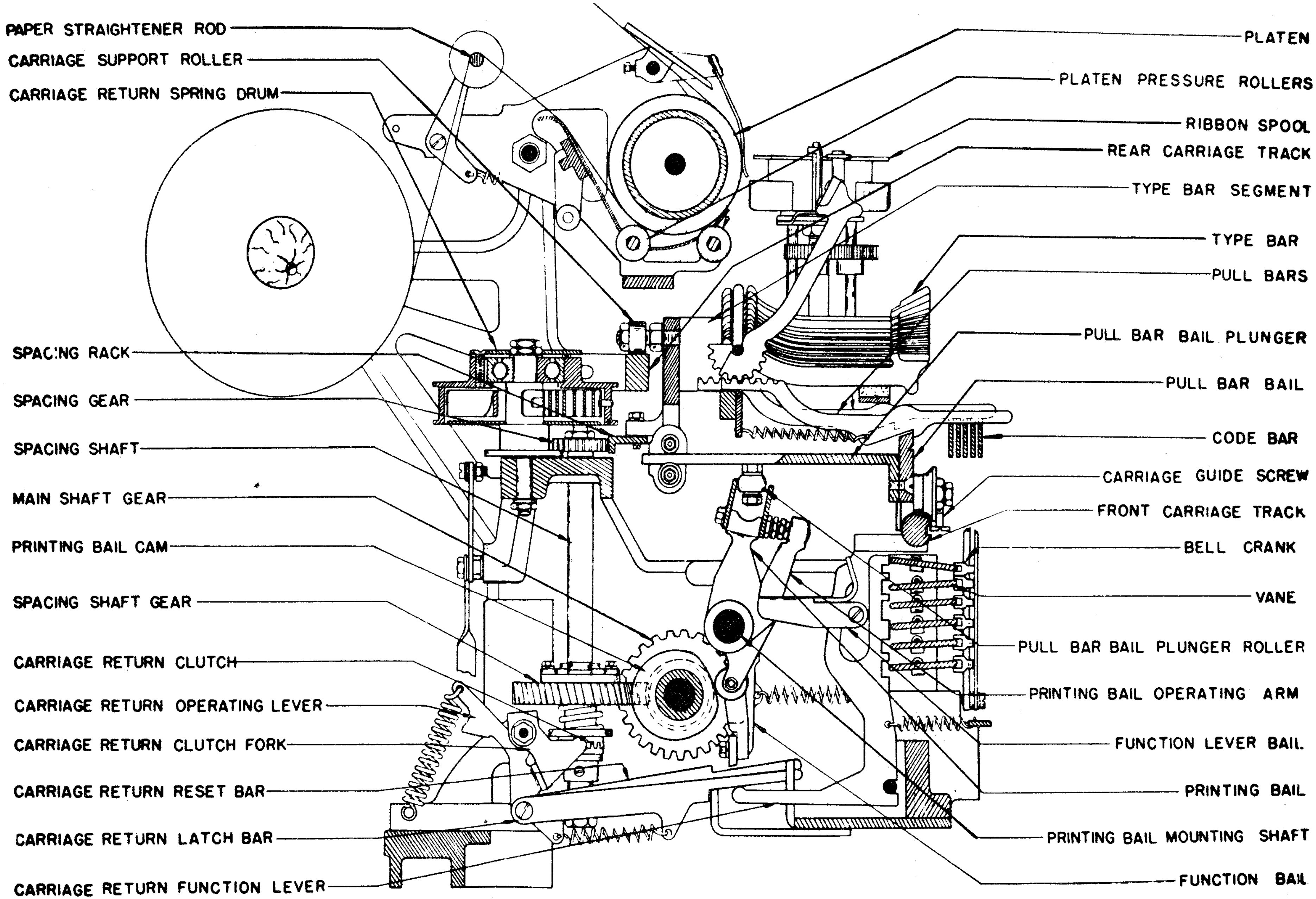


Figure 167.—Printing, from motor to type bar.

TYPING UNIT

If the character we just selected is received by a model 15—operating alone or as a component of a model 19 set —it is the typing unit which will cause the letter to be printed. The typing unit has type bars similar to those of a standard typewriter. By means of a selector mechanism, the incoming signals set up five code bars which, in turn, permit the correct type bar to strike the platen. The path of this force may be traced from the motor through the main shaft, the printing bail cam, the printing bail operating arm, the printing bail, the plunger roller, pull bar plunger, pull bar bail, and finally to the type bar (fig. 167).

The motor which drives the main shaft assembly of the typing unit supplies power to all mechanically operated parts of the machine. It may be constant speed synchronous operating only on regulated a. c. current, or governed speed, operating on a. c. or d. c. current.

LINE RELAY

A line relay base is provided on the model 15 printer (mounted on a bracket located to the rear of the typing unit) so that a line relay may be used.

The wiring is arranged so that either the line relay or the selector magnets may be connected in the line circuit. In the former case, the contacts of the line relay repeat the signals to the selector magnets, whereas, in the latter, the selector magnets are connected directly to the line.

WIRING DIAGRAMS

The wiring diagrams (figures 168 and 169) show the theoretical wiring of a typical model 15 printer. The motor circuit shown is for use with 110-volt direct current motors. (Be sure you refer to ACTUAL wiring diagrams for circuits used with other types of motors.)

The top figure on the wiring diagram shows the motor and the motor control circuits. When mechanical motor control is used, loops *A′ B′* and *G′ H′* are open, and *A′* is connected to *A*, *B′* to *B*, *G′* to *G*, and *H′* to *H*. When control relay is used, loops *A′′ B′′*, *C′ D′*, and *E′ F′* are open and *A′′* is connected to *A*, *B′* to *B*, *C′* to *C*, *D′* to *D*, *E′* to *E*, and *F′* to *F*.

The bottom figure on the wiring diagram shows the line and line relay circuits.

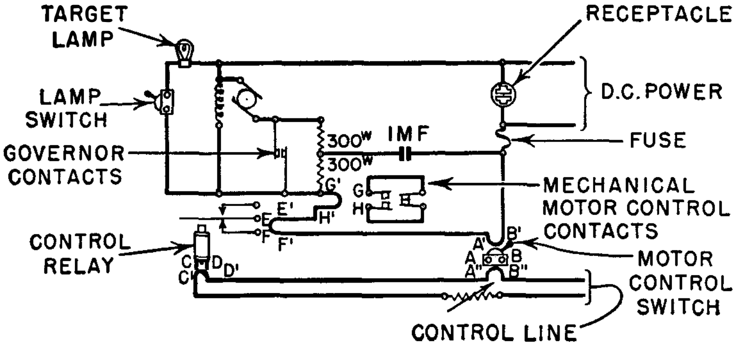


Figure 168.—Motor and motor control circuits.

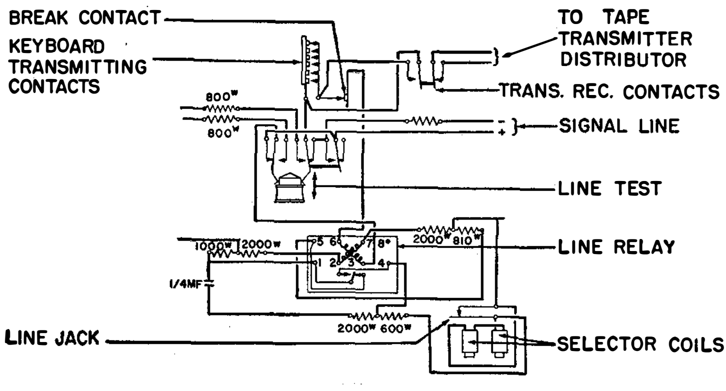


Figure 169.—Line and relay circuits.

MOUNTING THE MODEL 15

Motor Unit

The model 15 printer motor unit, typing unit, and keyboard unit should be mounted on the base unit in the order named.

The motor unit is mounted on the rear right-hand corner of the base by means of three hexagon head screws. These screws are found in place on the base. Mount the motor pinion to the motor shaft using the screw and lock washer found in the shaft. The steel motor pinion is shipped with its associated main shaft bakelite gear in a separate container. Remove the three motor unit mounting screws from the base and slide the motor unit in against the spring contacts. Holding it in this position, put the three mounting screws in place. Tighten the two front screws and then back them off about one-fourth of a turn. Do not tighten the rear mounting screw until the typing unit is in place.

Typing Unit

Underneath the typing unit you'll find two hexagonal studs which protect the typing-unit mechanism from injury when setting the unit on a bench, table, etc. These two studs enter clearance holes in the base unit.

Assemble the bakelite gear to the main shaft as follows: first remove the oil-retaining plug from the right end of the shaft. Then remove the clamping screw and lock washer that hold the gear hub to the shaft and slide the gear hub off the shaft. Remove the three screws and lock washers from the hub and assemble the bakelite gear and hub, inserting the three lock washers through the counter-bored holes of the gear. The gear hub with gear should then be slipped on the main shaft with the gear hub towards the outside of the typing unit until the slot on the main shaft permits the gear hub clamping screw with lock washer to be fastened in place.

The typing unit is held to the base unit by three thumb screws. Remove these screws from the base. The exact location of the typing unit on the base unit is determined by two dowel pins located in the two forward machined surfaces of the base unit. The right-hand dowel pin fits into a hole in the typing unit casting, while the left-hand dowel pin fits into a slot cut in the casing.

When you set the typing unit on the base unit, be very careful not to jam the bakelite main shaft gear against the motor pinion.

In lifting the typing unit, face the front of the unit. With the right hand, take hold of the flat projection on the right-hand typing unit casting. With the left hand, take hold of the extreme lower front corner of the left-hand casting. Lifting and moving should be done carefully so as not to put any part under undue strain which might throw it out of adjustment.

When setting the typing unit on the base unit, first lower the left side down all the way, holding the right side so that when the left side is resting on the base unit the main shaft gear is just ready to mesh with the motor pinion. Now with the left hand turn the motor flywheel, while at the same time you lower the right end of the typing unit, taking care that the motor pinion properly meshes with the main shaft gear.

Alinement of Motor Pinion and Main Shaft Gear

For printers equipped with motors having elongated mounting holes use the following method for alining the motor pinion and main shaft gear. Face the front of the base unit and with the keyboard removed from the base, visually check the lateral alinement of the motor pinion and the main shaft gear to determine if a center line of the gear coincides with a vertical line through the center of the hole in the motor pinion. If these lines do not coincide, remove the typing unit from the base unit and loosen the four-motor mounting screws.

Replace the typing unit on the base unit, and shift the motor to obtain the foregoing condition as nearly as it is possible to determine by eye. See that the edges of the motor base are parallel to the edges of the motor plate. Then remove the typing unit and tighten the four-motor mounting screws.

Loosen the rear motor-plate mounting screw and the lock nut on the motor-plate adjusting screw. Replace the typing unit and tighten the three-typing unit-mounting thumbscrews. By means of the adjusting screw, adjust the vertical position of the motor pinion until there is a barely perceptible amount of backlash between the motor pinion and the main shaft gear, at the point where there is the least amount of backlash in one complete revolution of the main shaft.

Apply a film of grease to the motor pinion.

Start the motor. Carefully readjust the vertical position of the motor pinion, by means of the adjusting screw, until the gear noise is reduced to a minimum.

Be careful when you adjust the vertical position of the motor pinion while the motor is running. Otherwise you may damage the main shaft gear or reduce the speed of the motor as the result of too close a mesh between the gear and the pinion.

Tighten the three motor-plate mounting screws and the adjusting screw lock nut. Recheck the backlash between the motor pinion and the main shaft gear.

For printers equipped with motors not having elongated mounting holes make adjustments as described in the foregoing, except that in making the first adjustments the motor-mounting holes may not permit accurate gear alinement. In this case the motor should be adjusted to provide the best possible gear alinement.

Keyboard Unit

When mounting the keyboard unit to the base unit, be very careful not to jam the bakelite gear on the keyboard unit against the steel gear with which it meshes on the main shaft of the typing unit.

The keyboard unit slides into the opening in front of the base unit upon two angle irons acting as rails. The two plates, fastened under the keyboard unit on the right- and left-hand sides, go under the rails. The keyboard unit is held in place by means of the two thumbscrews located on the keyboard unit.

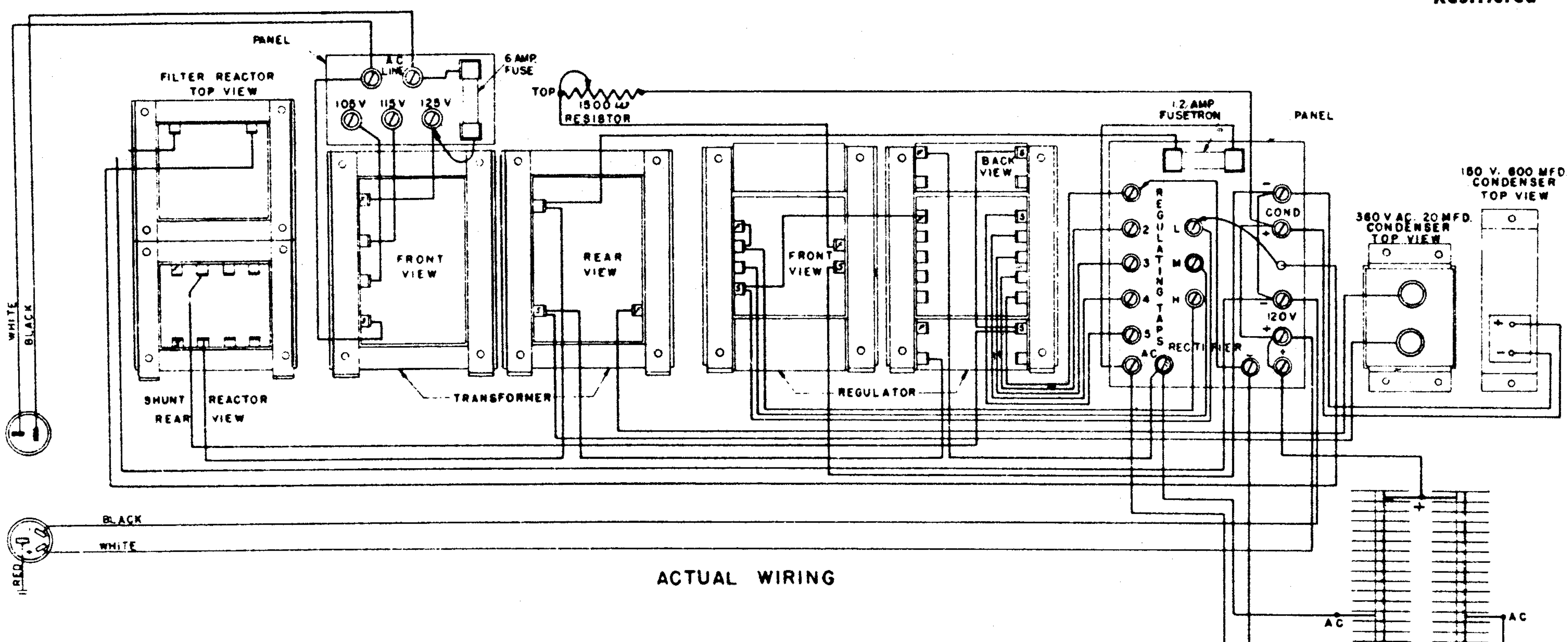
Slide the keyboard unit into place slowly and, at the same time, rotate the motor flywheel back and forth so that the keyboard unit gear will mesh properly with the gear on the typing unit. When the keyboard unit is in place, tighten the two thumbscrews.

Keep in mind that all printers are thoroughly lubricated in the factory. However, if the printers are not installed shortly after they are received, or if any lack of lubrication is apparent, it is advisable to lubricate the machine immediately before installation according to the lubrication specifications. An extra lubrication should be given a new machine when it has been in service approximately half the time normally allowed between lubrications.

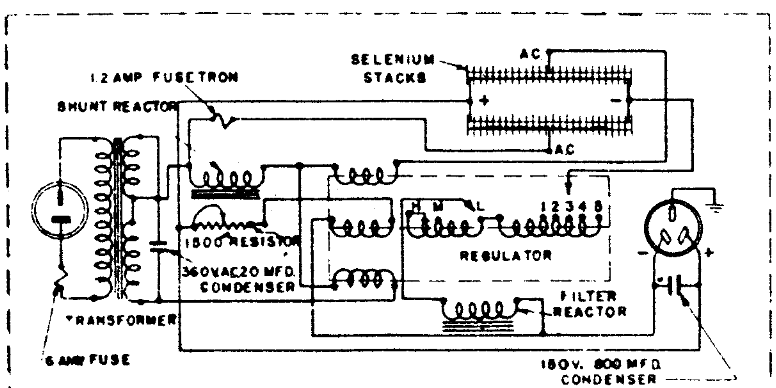
REC–13 RECTIFIER

When 60-cycle synchronous motors are used, the REC–13 rectifier (rated for 60 cycles only) may be used for providing direct current suitable for either local or signal line battery. The REC–13 rectifier includes power factor correction which is advantageous when using synchronous motors.

The REC–13 rectifier is designed to deliver continuously 0.6 ampere at 120 volts d. c. from a 105- to 125-volt 60-cycle a. c. single-phase power supply. It consists of an insulated type input transformer with primary taps, a full-wave selenium rectifying element, a power factor correction condenser, a filter consisting of a choke and condenser, a bleeder resistor, and a regulator with taps. All parts are secured to a metal base which has rubber



ACTUAL WIRING



SCHEMATIC WIRING

Figure 170.—Wiring diagrams of model REC–13 rectifier.

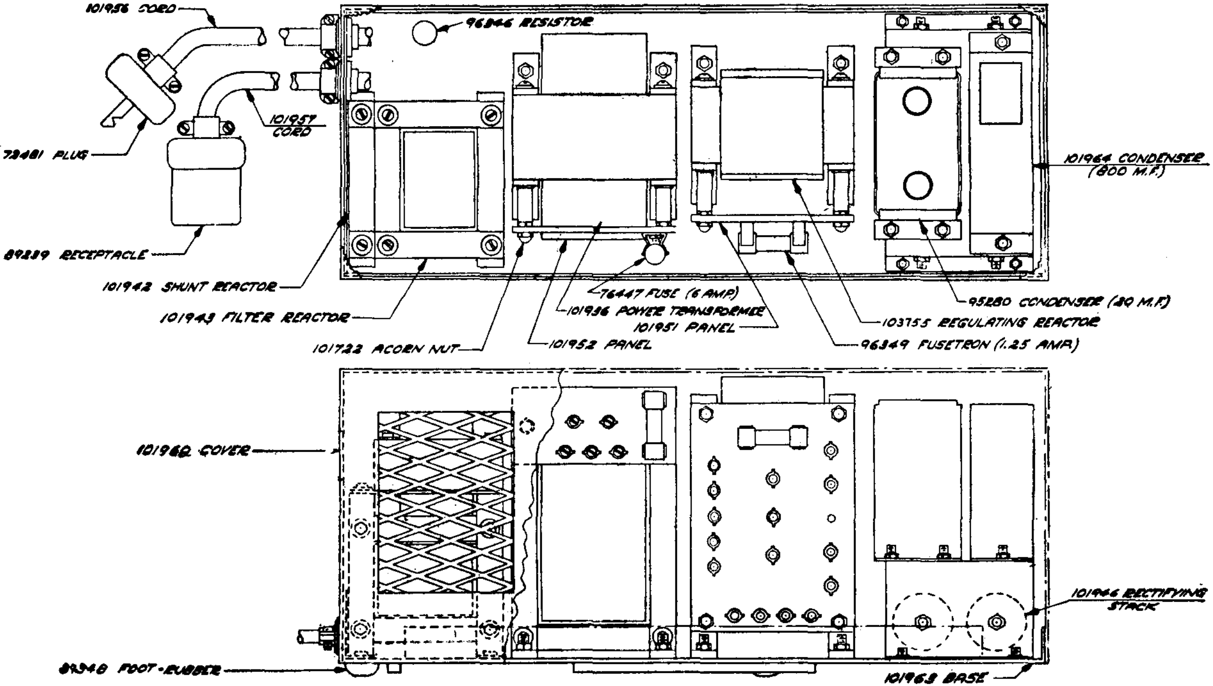


Figure 171.—Assembly drawing, model REC–13 rectifier.

Restricted

feet for shelf mounting. The rectifier is furnished complete with cover, cords, and plugs for making a. c. and d. c. connections. The metal cover which is fastened to the base by means of screws is finished in black wrinkle enamel. The approximate dimensions of the rectifier are 20¼ inches long, 8 inches wide, and 9 inches high. The REC–13 is rated as follows:

Input: 105 to 125 volts, 60-cycle a. c. single-phase.
Output: 0.6 ampere at 120 volts d. c.
A. c. component in d. c. output voltages: 1 percent r. m. s. at 0.6 ampere load.
No-load voltage when new: Not over 135 volts.

Adjustments

This rectifier is provided with a door in the front of its cover to permit access to two regulating panels within the cover. The left-hand panel has terminals for the transformer primary taps which are marked for input voltages of 105, 115, and 125. A 6-ampere fuse for protecting the transformer is also mounted on this panel. A flexible lead is used for connecting alternating current to the proper primary tap. The selection of the primary tap will depend on the voltage of the a. c. power supply. In no case should the connection to these taps be changed for the purpose of regulating the d. c. output voltage.

To regulate the d. c. output and to compensate for aging of the rectifying element, three coarse regulator taps marked *L*, *M*, and *H* and five fine regulator taps marked 1, 2, 3, 4, and 5 terminate on the right-hand panel. The regulating taps are set at the factory on *L* and either 1, 2, or 3 to deliver a minimum of 120 volts d. c. at 0.6 ampere. Each fine tap will change the d. c. output voltage approximately 2 volts and each coarse tap approximately 8 volts when the d. c. current is 0.5 ampere. The method normally employed in checking the d. c. output of this rectifier is to disconnect all apparatus from the d. c. side and connect a 60-watt light bulb in series with a suitable ammeter across the output. For correct adjustment of the output, the flexible leads should be connected to those taps which will cause the ammeter to register a current flow which is nearest to but not less than 0.5 ampere. You should check this adjustment when the rectifier is installed and periodically thereafter. The amount of aging will be somewhat greater during the first few months of use. After this, the rectifier should operate for long periods without the necessity of readjusting.

If at any time you find it necessary to use the maximum regulating tap to obtain the proper output current, the rectifier should be withdrawn from service and repaired.

A 1.25-ampere fusetron is located on the right-hand panel for overload protection in the output circuit.

Figures 170 and 171 show the actual and theoretical wiring of the rectifier. An assembly drawing giving the names and numbers of the component parts is shown in figure 171.

HERE IS A WORD OF WARNING: The secondary voltage of the power transformer is 300 volts. All the control elements including the power factor correcting condenser are therefore 300 volts above ground potential.

REC–30 RECTIFIER

The REC–30 rectifier is equipped with multivoltage, multifrequency connecting taps which permit printers, transmitter-distributors and reperforators driven by 50–60-cycle series governed motors to be operated on alternating current power supplies of approximately 95 to 125 or 190 to 250 volts; and 25, 40, 50, or 60 cycles. Since this rectifier is to be generally used with series wound motors, no provision has been made for power factor correction.

The power unit consists essentially of an auto-transformer, necessary control and filament windings for the operation of the grid-control rectifier network, an insulating-type plate transformer, suitable radio interference filters on both a. c. input and d. c. output circuits, d. c. output filter consisting of a choke and two condensers, resistor network, two grid-controlled rectifier tubes, one voltage standard tube, and one amplifier tube. All of these parts are secured to a metal base which has metal feet for shelf mounting. The approximate dimensions of the power unit are 25 inches long, 8 inches wide, and 11 inches high. The approximate net weight is 110 pounds.

Double Pole-power Switch

The double pole-power switch when thrown in the OFF position, completely isolates the fuses and flexible leads from the a. c. supply. You should always be careful to throw the switch to the OFF position before opening the hinged door of the rectifier cover. Any terminal on the main terminal panel may be 250 volts above ground potential with the switch in the ON position.

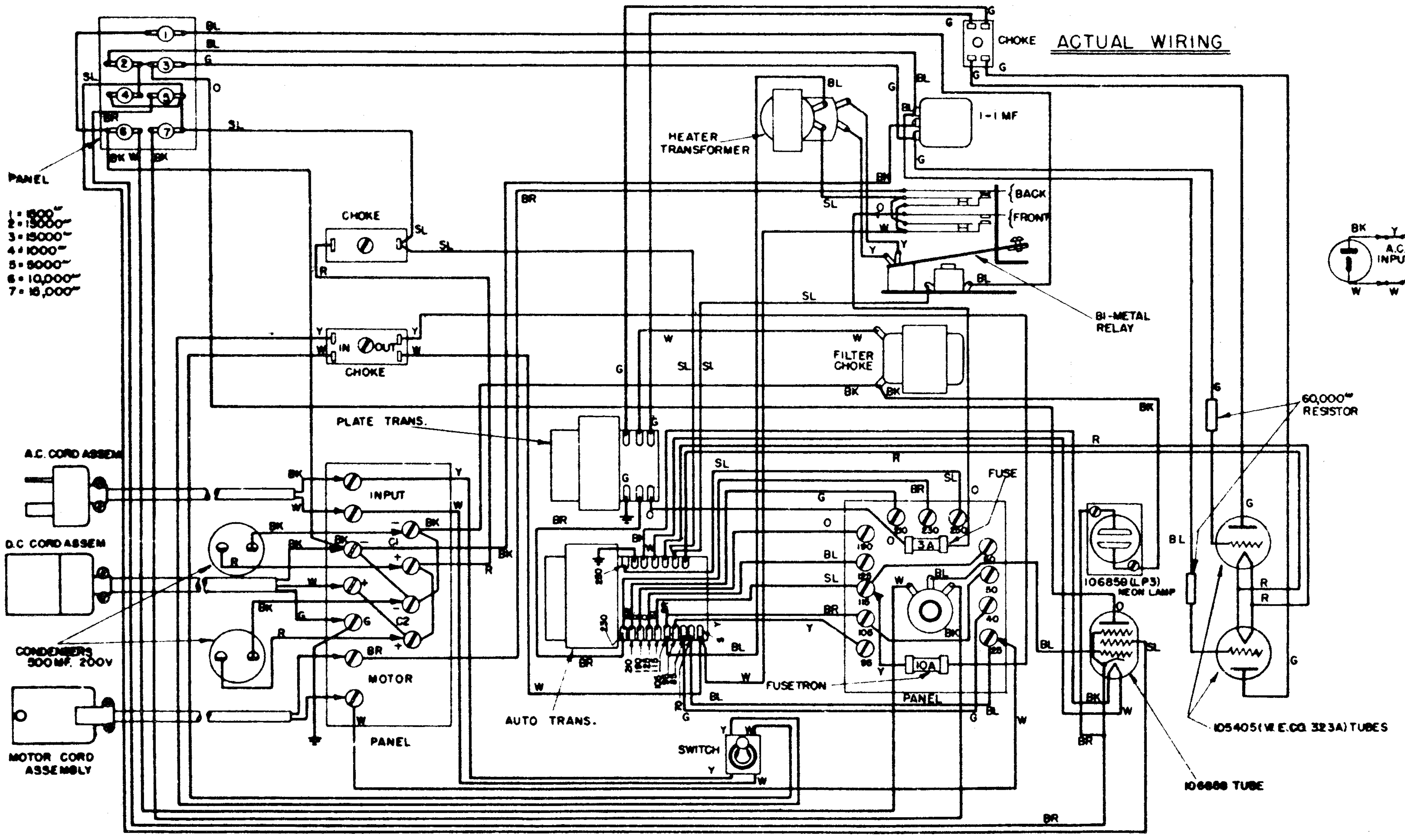
Main Terminal Panel

The main terminal panel, which is located directly behind the hinged door in the cover, contains terminals for a. c. input taps, a. c. output taps, fuses and potentiometer. The a. c. input taps for the line voltages of 95, 105, 115, 125, 190, 210, 230, and 250 volts are located on the top and left-hand side of the panel. The a. c. output taps to proper adjusted voltage for operating series governed motors on frequencies of 25, 40, 50, or 60 cycles are located on the right-hand side of the panel.

The a. c. input, a. c. output and d. c. output cords and two filter condensers terminate on a panel at the left-front of the rectifier. The cover must be removed to gain access to this panel.

Adjustments

In order to make adjustments, throw the power switch to the OFF position and open the hinged door of the



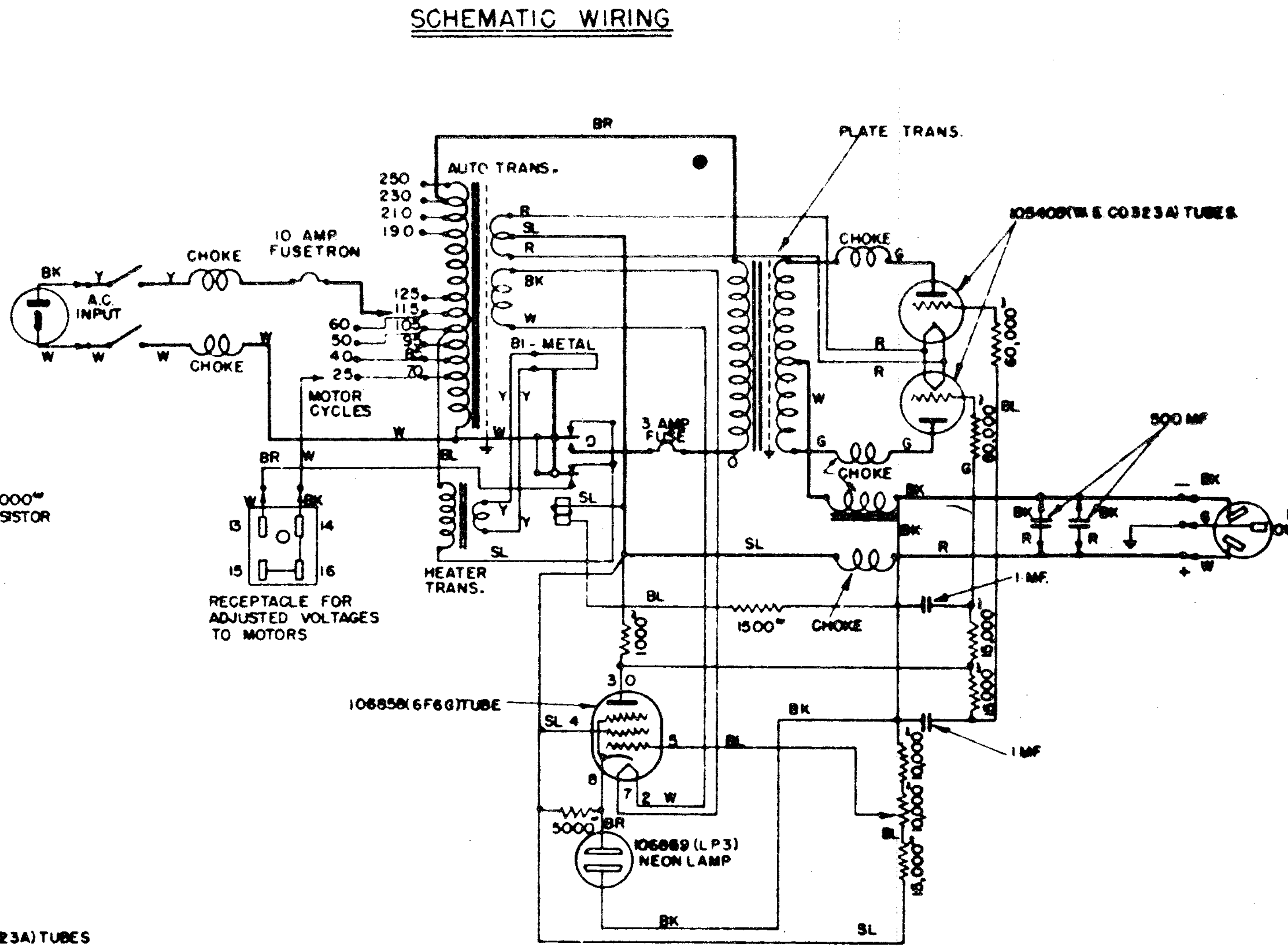


Figure 172.—Wiring diagrams of model REC-30 rectifier.

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cover. Do not make any adjustments or change any tubes while the unit is in operation. The secondary voltage of the transformer is 400 volts.

To adjust for a. c. input voltage, connect the flexible lead on the left-hand and top side of the panel to the terminal with the markings which most nearly corresponds to the voltage of the available a. c. supply.

To adjust for frequency, connect the flexible lead on the right-hand side of the control panel to the terminal having a marking which most nearly corresponds to the frequency of the available a. c. supply.

To adjust the d. c. output voltages, connect a 60-watt, 115-volt lamp in series with a suitable ammeter across the d. c. output of the rectifier and adjust the potentiometer with screw driver slot located in the center of the top panel until the ammeter reads 0.5 ampere.

It will be necessary for the a. c. current supply to be connected to the power unit for approximately 20 seconds before d. c. output will be available. This time delay is necessary for the protection of the grid-controlled rectifier tubes. Check this adjustment when the unit is installed and periodically thereafter. The time delay may be adjusted by means of the adjusting screw and lock nut located on the tie bar between the two bimetal strips. The time delay is located under a metal cover at the top of the door opening. The cover is removable by loosening one screw and sliding the cover off to the right.

Operation

If the d. c. output fails to become available within approximately 1 minute after the power switch is turned on, make sure that:

1. The input fuse (lower one on the main terminal panel) is not burned out.

2. The plate transformer fuse (upper one on the terminal panel) is not burned out.

3. The front "make" contact of the relay (contact nearest the door of the cabinet) is in contact with its associated contact.

4. The filaments on both grid-controlled rectifier tubes are lit.

5. The bimetal pulls the relay armature down.

If the bimetal does not pull the relay armature down, check the back contacts (normally closed) of the relay. These contacts in multiple are in series with the primary winding of the heater transformer. If the bimetal is inoperative and these contacts are making, the heater transformer is probably at fault. The unit may be manually started by depressing the relay armature with a stick or other piece of nonconducting material. Once closed the relay coil will hold in.

If the d. c. output rises considerably or if the rectifier output does not regulate properly, either the neon lamp and/or the amplifier tube may be defective. If a high enough output voltage cannot be obtained, one or both of the rectifier tubes may need replacement. If the line voltage drops considerably below the a. c. input line voltage setting, the d. c. output voltage will drop. In this case, the lower a. c. input line tap should be used to match the actual line voltage.

In the event that the time delay relay fails to hold down magnetically and the bimetal remains hot, check the relay coil and/or resistor in series with same. This could affect both the a. c. and d. c. outputs.

Instruction books which come with the equipment will furnish actual and schematic wiring of the REC–30 rectifier. You should consult these when performing work on the equipment.

THE TRANSMITTER-DISTRIBUTOR

The transmitter-distributor is a motor-driven device which translates code combinations, perforated in a paper tape, into electrical impulses and transmits these impulses to one or more receiving stations. The tape may be perforated by any one of several models of teletypewriter perforating or reperforating machines.

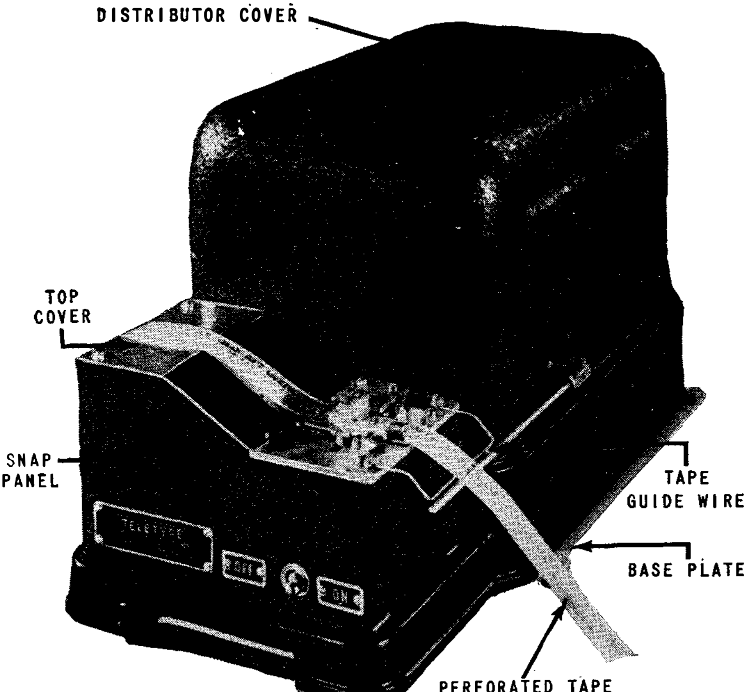

Figure 173.—Transmitter—distributor.

The portion of the unit through which the perforated tape feeds is known as the transmitter (fig. 175). Its function is to prepare electrical paths to the commutator segments of the distributor (see figure 176). These paths are controlled by tape pins which sense the perforations in the tape and thereby determine the positions of the contact tongues (fig. 177) with relation to their upper and lower contact screws.

The distributor completes the connections of the signal line. Connections are made in sequence at a constant rate of speed by brushes which traverse the segments and the collector ring.

As in the case of the model 15 printer, mechanical actions of the T–D can be only briefly sketched here.

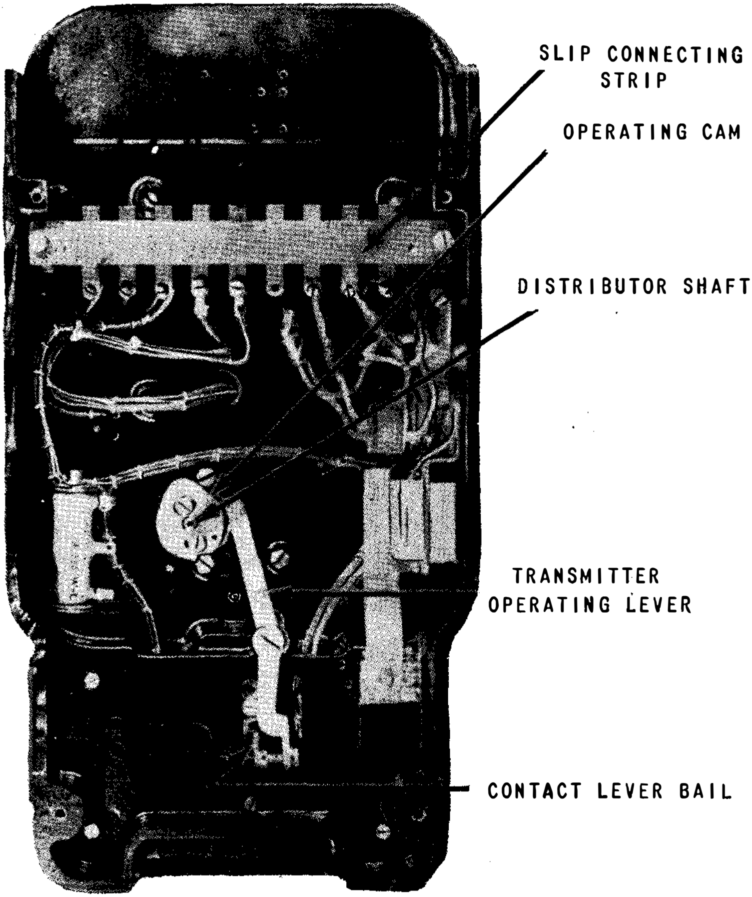

Figure 174.—Transmitter—distributor, bottom view.

THE TAPE SENSING MECHANISM

The contact levers (fig. 177) are positioned vertically in the transmitter. They pivot on a shaft, *S*, and have extensions to the right, *C*, left, *A*, and downward, *B*. The right-hand extensions project upward at the ends and have tape pins embedded in them. An opening is provided in a tape guide, located above the right-hand extensions of the contact levers, to permit the tape pins to enter the code holes in the tape. The left-hand extensions of each contact lever carries a contact tongue which is attached to the contact lever by a pivotal mounting. Each contact tongue is positioned to move between two contact screws—a spacing contact screw above, and a marking contact screw below. A contact lever spring is attached to the mounting end of each contact and tends to hold it against the lower contact screw.

A contact lever bail, pivotally mounted just below contact lever lower extensions, has an arm extending downward engaging a transmitter operating lever. This transmitter operating lever (fig. 174) has a central pivot screw and moves in a horizontal plane. A roller on the rear end of the lever rides a transmitter operating cam mounted on the lower end of the distributor shaft. The motion imparted to the transmitter operating lever by the operating cam causes the contact lever bail to rotate the contact levers on their shafts sufficiently to move the contact tongues up and down between the marking and spacing contact screws. After the tongues strike the upper screws, any additional clockwise rotation of the contact levers is absorbed by the contact lever springs.

When the distributor brush comes to rest on the stop segment (fig. 175) the transmitter operating lever roller is on the peak of its cam, thereby holding the tongues against the spacing contacts and also holding the tape pins, located in the right-hand extensions of the contact levers, below the holes in the tape. As the transmitter operating lever roller rides to the low part of its cam, the tape pins rise. If tape perforated with code combinations is in the tape guide at this time, the contact lever pins will project through the tape wherever the tape is perforated and permit the associated contact tongues to rest on the marking contacts, while the pins will be blocked at the unperforated portions and the associated contact tongues will be held against the spacing contacts. The tape will be held stationary and the contact tongues will maintain their positions as determined by the code perforations while the distributor brush is transversing segments one to five inclusive. The inner distributor will transmit marking impulses to the line from segments associated with tongues that rest on the lower contacts, and spacing impulses from segments associated with tongues that are on the upper contacts.

THE DISTRIBUTOR MECHANISM

The distributor (fig. 175) is made up of two concentric conducting rings mounted on a fiber disk. The outer ring is divided into seven segments. Segments one to five, inclusive, correspond to the five intelligence intervals of the 5-unit code and are connected to the five contact tongues shown in figure 161.

Immediately preceding segment No. 1 is the start segment. The segment following segment No. 5 is the stop segment. The stop segment and the lower contact screws are permanently connected to marking-line battery. (As you probably know, the term "battery" doesn't mean a cluster of dry cells. Here it designates the current potential applied to the line.) When the distributor brush passes over the start segment, a spacing impulse is always transmitted, whereas a marking impulse always results when the brush traverses the stop segment. These two invariable impulses cause the receiving mechanism to operate in unison with the distributor brush arm.

Positioned to the rear of the contact levers and pivoted on the contact lever shaft is a feed lever which is similar

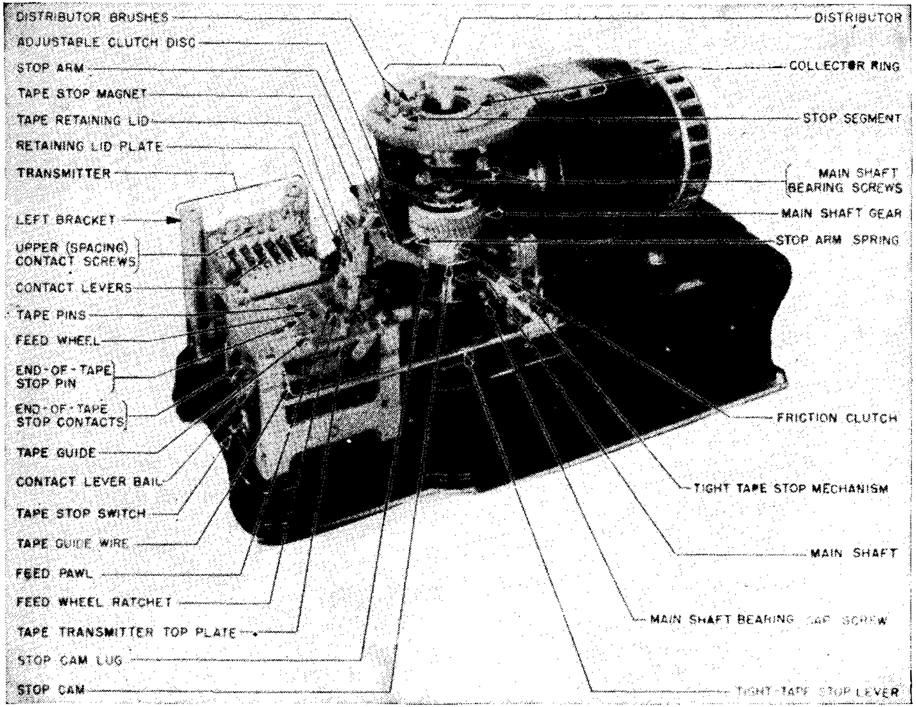

Figure 175.—Transmitter—distributor, cover removed.

in shape to a contact lever. The feed lever has a spring attached to its left-hand extension and a feed pawl mounted on its right-hand extension, *C*. A feed-pawl spring holds the feed pawl in contact with a feed-wheel ratchet. Pins on the circumference of the feed wheel

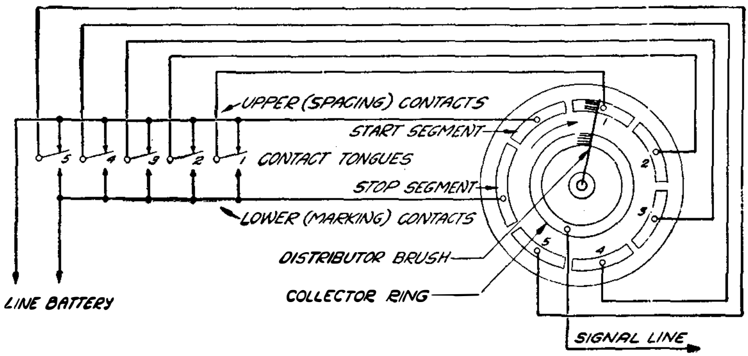

Figure 176.—Distributor segments and wiring.

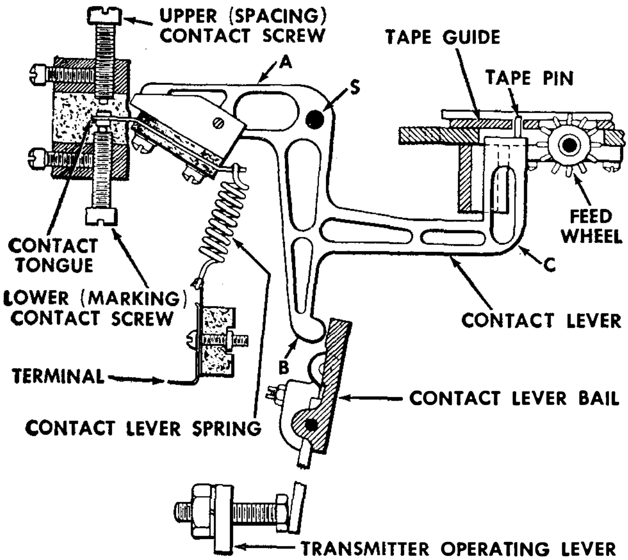

Figure 177.—Contact assembly.

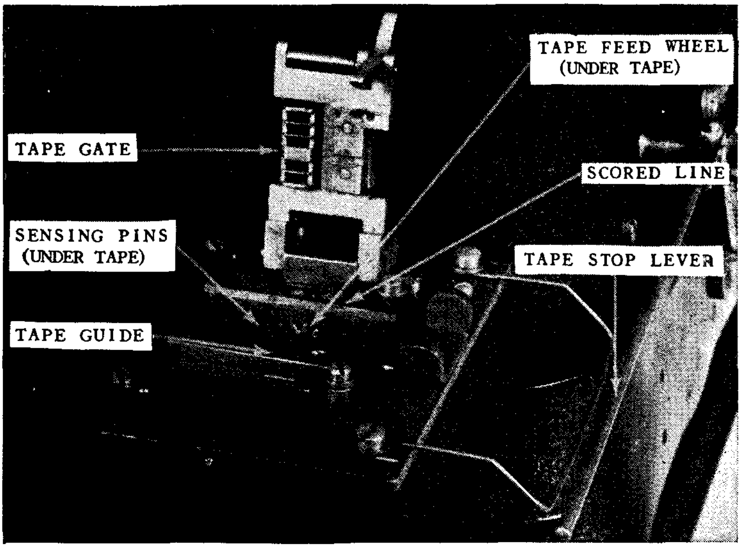

Figure 178.—Transmitter—distributor showing tape guide and sensing pins.

(fig. 177) project through an opening in the tape guide and mesh with the feed holes in the tape. A retaining lid, under which the tape passes, holds the tape in contact with the feed-wheel pins. When the action of the contact lever bail on the contact lever moves the tape pins downward, the feed lever responds in a similar manner, causing the feed pawl to engage a tooth on the feed-wheel ratchet and rotate the feed wheel. With each downward motion of the feed pawl, the tape will be advanced from right to left the distance required to bring the succeeding code combination over the tape pins. The setting of the feed pawl is such that it does not start to rotate the feed wheel until the tape pins have moved clear of the tape. The feed-wheel detent is provided to insure alinement of the code perforations with the tape pins. The position of the operating cam with relation to the distributor brush is such that the contact tongues are not moved from the lower contacts until after the brush has reached the stop segment. While the brush is passing over the stop segment, the tape is advanced.

SYNCHRONOUS AND GOVERNED MOTORS

Where regulated a. c. power is available, a synchronous motor may be used, otherwise governed motors must be used. Governed motors are available for operation on either a. c. or d. c. power. The speed is controlled by a centrifugal contact mechanism having commutator rings or disks. In general, motors are mounted directly to the base casting and the resistors and condensers used with governed motors are mounted on the base and in the base cavity. However, some governed motors are mounted to a base plate having governor resistors and a condenser mounted on it so as to form a complete motor-unit assembly.

When an a. c. governed motor is used, a contact assembly is provided which is operated by the tape stop magnet stop arm (fig. 179). The purpose of the contact assembly

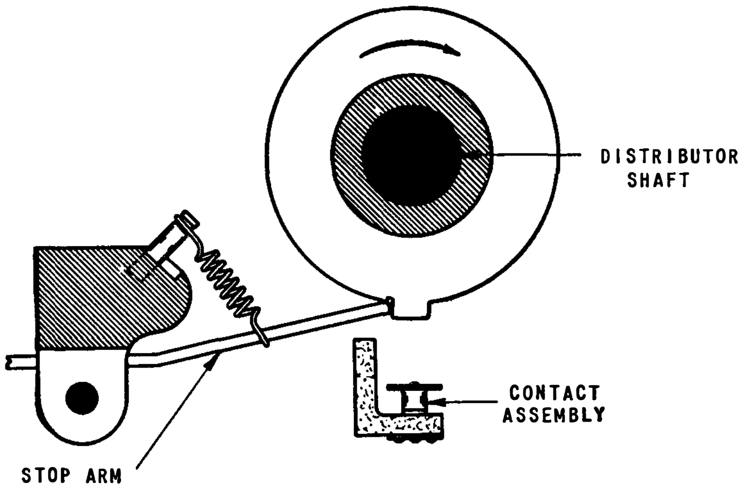

Figure 179.—Distributor shaft and stop arm.

is to provide better speed control by introducing a resistor in series with the motor when the distributor shaft is rotating, and by shunting the resistor when the load of the friction clutch is added to the motor.

INSTALLING THE MODEL 14 T-D

The model 14 transmitter-distributor is assembled at the factory. Installation, therefore, requires only that the machine be slid into position on the base plate. No wire connections are required, since necessary contact is made by a slip connecting strip. The transmitter-distributor can be removed from the base plate by lifting and pulling forward. Aboard ship a positive lock is furnished to make sure the T–D is not dislodged by the movement of the ship.

SWITCHBOARD OPERATION

The switchboard for teletypewriter operation resembles a regular patch panel for any other radio circuit. One thing to remember about operating the patches in the teletypewriter switchboard is that you must never pull the patch from the machine jack first. If you do, this will cause the machines in the line, whether local or remote, to run open. This is due to the fact that the outgoing line is shorted. The proper way is to take the looping patch out first. If the patch is inserted firmly into the looping jack, the operators of the other machines in the line will never know when you have plugged into them, or when you disconnect from the line.

You may also use the switchboard for plugging in reperforators, either typing or nontyping. This is done in the same manner as described above.

LUBRICATION AND CLEANING

The most important factor in maintenance of station equipment is proper lubrication and cleaning of the machine. Lubrication does not mean drenching the teletypewriter with oil or swabbing it with grease. Too much lubricant will in a short time collect dust and grit and oilsoak the wiring. A machine in this condition will be subjected to excessive wear and deterioration of insulation. Such machines are a source of constant trouble as well as a fire hazard.

Cleaning

Always clean a teletypewriter before lubricating it. During the cleaning process the power should be disconnected except as otherwise stated. Old grease and dirt should be removed from around points where grease lubrication is specified with a KS–6320 orange stick or a piece of fiber. Avoid wiping old grease or dirt into wearing surfaces, as this makes it difficult or impossible for fresh lubricant to work its way in. Avoid disturbing the springs or adjustments.

A clean dry piece of cheesecloth should be used for cleaning. It may be wrapped around a screw driver or an orange stick to reach points not readily accessible.

CLEANING THE TYPE.—Insert a doubled piece of cheesecloth between the type bars and the backstop to catch the dirt and excess cleaning fluid. Clean the type thoroughly with a piece of cheesecloth moistened with carbon tetrachloride. Use the cleaning fluid sparingly to avoid getting it on other parts of the machine. Then brush the type with a dry typewriter brush.

CLEANING THE SELECTING MECHANISM.—The code bar bearings, *T* lever pivots and the sword and selector lever assembly between the separator plates should be cleaned without disassembling. Pour over each assembly about a teaspoonful of carbon tetrachloride. Hold a rag underneath the mechanism during the cleaning process to catch the drippings. The cap of the carbon tetrachloride can usually is a convenient measure for the cleaning fluid.

CLEANING THE KEY CAPS.—Clean the key caps with a cloth slightly moistened with water. (Do not use carbon tetrachloride on rubber caps.)

TRANSMITTING CONTACTS.—The transmitting contacts should not be cleaned or filed unless there is definite evidence of keyboard trouble. To clean the contacts use a clean contact burnisher. If it becomes necessary to use a file, use only a few light strokes because the contact metal is very soft. After filing, wipe out the space between the springs with a piece of cheesecloth wrapped around a thin flat tool or piece of fiber, and burnish the contacts with a clean burnisher. If cleaning, filing, or burnishing is done a check of the adjustments must be made.

MOTOR-STOP CONTACTS.—Clean with cheesecloth dampened with carbon tetrachloride, then burnish the contacts.

SERIES TYPE MOTORS: BRUSHES.—In removing the brushes, note or mark the position so that each brush may be replaced in the same holder and with the same side uppermost. If the brush has a number stamped on the carbon, this may be used as a guide.

There should be at least 5/16 of an inch of brush material remaining. The surface bearing on the commutator should constitute a considerable portion of the brush face, and the contacting surface should extend across at least three-fourths of the long dimensions of the brush face. If these requirements are not met, substitute a brush which has been properly surfaced.

A teletypewriter motor, like any other motor, requires proper care and upkeep. Cleaning is an important factor. Don't neglect the brushes commutator, slip rings, and contact disks.

Lubrication

The machine—model 15 or T–D—is ready for lubrication when it has been thoroughly cleaned and all cleaning fluid has been removed from the parts. The lubrication should be in accordance with the following general instructions and AT THE PARTICULAR POINTS SPECIFIED IN EQUIPMENT BULLETINS.

The different kinds of teletypewriter lubricants are used as follows:

1. Oil—for small moving parts.
2. Grease—for heavy moving parts.
3. Oil-grease-oil—for ball bearings.

Springs require a small dab of grease where the spring hooks into a retaining hole or grommet. Bushing-type bearings have a small oil cup which should be kept filled. All fiber and all metal gears require a small amount of oil. Friction washers on the selector unit and the main shaft in the transmitter-distributor are lubricated by forcing the point of a screw driver beneath the felt washers and thoroughly oiling the felt washers.

An oil can having a spout at least 3 inches long and with the tip curved will be most useful for applying oil. Grease should be applied with a number 88975 (KS-3819) grease gun, or, where that is not available, by a toothpick, screw-driver blade or similar instrument.

Here is an important point.—Instruction books specify two or three strokes of the grease gun for lubricating motor bearings. These instructions are NOT to be followed. Actually grease is packed about the bearing when the motor is assembled; in routine lubrication TWO OR THREE DROPS OF OIL are used to soften the grease already packed about the bearing. In no case should you attempt to inject grease in a motor bearing with a grease gun.

When lubricating fiber or bakelite gears, use only a minimum amount of lubricant. Otherwise, the gears will become saturated, expand, and the resulting mesh will be too close.

Always follow instructions when cleaning and lubricating teletypewriter equipment. Troubles frequently develop from careless cleaning and lubrication.

QUIZ

1. Teletypewriters may be equipped with either series-governed or synchronous motors. Which type requires a steady 60-cycle current?
2. The model 19 set has a switching arrangement that permits three conditions of traffic transmission. Name them.
3. What is the primary function of a teletypewriter keyboard transmitting unit?
4. What is the purpose of saw-toothed shaped notches on the selector bars?
5. When installing a typing unit, what special regard should be given the bakelite main shaft gear?
6. What is the fundamental difference between REC–13 and REC–30 rectifiers?
7. When it is necessary to use the maximum regulating tap to obtain the proper output current on the REC–13, what action must be taken?
8. In the model 14 transmitter-distributor the outer distributor ring is divided into segments. How many segments are there, and which are used to transmit intelligence?
9. What are some of the results of overlubrication of teletypewriter equipment?
10. Why is it inadvisable to use a grease gun to lubricate a motor bearing?

CHAPTER 13

ABSTRACTING AND ACCOUNTING

BIG BUSINESS

The Navy has one of the largest communication systems in the world. It's big business, and like any other big business, there are books to be kept. To keep the records straight, messages are divided into classes, and definite procedures established for purpose of accounting.

Before proceeding with this chapter, be sure you thoroughly understand the various naval forms of messages, and the two commercial forms, international and domestic. A brief review of the appropriate section of *Joint Communication Instructions* or *Radioman 3 and 2,* NavPers 10228 will get you started right.

Most traffic handled by the Navy goes to or from other units of the Navy or other branches of the Armed Forces. This is military traffic and no accounting is involved, for there are no toll charges on these messages.

On the other hand, there are messages on which tolls must be collected—commercial messages, press releases, and a type of message (class E) which men at sea can use to communicate with members of the family back home.

But, let's talk of first things first. There are five classes of messages: A, B, C, D, and E. Most messages are class A. These are military messages for which there is no charge because they are handled all the way over military circuits. In short, class A messages are official messages of the Navy, Army, or Air Force entering Navy circuits, AND the REPLIES to such messages. Class A messages are handled in naval form when transmitted over naval circuits. If, for some reason, a class A message must be transmitted over commercial lines, it is put in commercial form.

The next class of messages is class B. In this group are all official messages of the United States Government departments OTHER THAN the Navy, Army, or Air Force. These messages are also transmitted over Navy circuits free of charge but tolls are charged for any commercial handling. The form here is different. Instead of naval form, class B messages are transmitted in COMMERCIAL form, usually international commercial form.

For a moment, let's go back to class A messages. You've been told that the replies to class A messages were also considered class A. There is this exception: when a government department replies to a class A message, that reply is class B, and therefore in commercial form.

Class C comes in for only limited use, so we'll pass over it quickly. Class C includes special forms of messages used to transmit data such as hydrographic information, weather, and time signals. This information is made available to ships of every nationality.

All class D messages are private messages on which full charges are collected for transmission over the entire route. Class D includes press—that is, newspaper stories filed by correspondents to their papers. When handled over Navy circuits, class D messages are serviced by Navy procedure, but the commercial form of the message is never changed. All ships and certain naval shore radio stations are open to class D traffic. *Joint Communication Instructions* provides a list of these shore radio stations.

Class E are private messages to or from naval personnel which are handled without charge over Navy circuits. On some class E messages you collect tolls, on others you do not. There is an easy way to know whether or not to collect tolls. If, before the message gets to its destination, it must be handled by a commercial company, you collect tolls for the distance which the message travels over commercial lines. Class E messages between units of the Navy go free of charge. This includes messages from one Navy ship to another, ship-to-shore, and shore-to-ship.

When a ship sends a class E message addressed to a person at a naval shore radio station, there are no charges. However, no relay is permitted over naval circuits within the continental limits of the United States unless the radio station to which the message is going is outside the United States. For example, suppose your ship is in the Pacific and receives for transmission a class E message addressed to someone at an air base in French Morocco. Your ship would transmit the message to Radio San Francisco. San Francisco would put the message on its point-to-point radio (but never landline) circuit to Washington, D. C. Washington would, in turn, relay it to Morocco.

In this case, the message is relayed within the continental limits without the use of commercial facilities. If, however, the message were addressed to a point in the United States, Western Union would handle it out of San Francisco and tolls would have to be collected.

COMMERCIAL TRAFFIC

As you study messages involving tolls, you'll come in contact with the term "commercial traffic." This refers generally to all traffic handled in international or domestic commercial form, and includes class E. It is traffic on which tolls are collected for transmission at commercial rates, and which is handled according to commercial practice and requirements.

Commercial traffic is a general term. To be more specific, let's reduce the term to its three components: radiotelegrams, cablegrams, and domestic telegrams. The first two are always in INTERNATIONAL commercial form, and the third is always in DOMESTIC commercial form. Each of these, in turn, can be briefly defined.

RADIOTELEGRAM is a message from ship-to-ship, ship-to-shore, or shore-to-ship. It is always in international form and is always transmitted BY RADIO over all or part of its route.

CABLEGRAM is a message transmitted from point-to-point in international form, BY MEANS OF CABLE, over all or part of its route.

DOMESTIC TELEGRAM is the ordinary Western Union telegram. It originates on shore and goes to a point on shore. It is transmitted in domestic form to points within the continental limits of the United States, Canada, Mexico, or Alaska. By international agreement, domestic telegrams as such cannot be addressed or transmitted to a ship at sea.

RELEASING COMMERCIAL TRAFFIC

On naval ships the procedure for filing commercial traffic is as follows: The message must first be approved by the commanding officer, or an officer designated by him, and duly released. The charges must be collected before the CO releases it. It is then filed with you. Then count the words and determine and collect the charges. Before collecting the charges, be sure to consult the communication watch officer or the Radioman in charge. You have to know which shore station is accepting the traffic to determine the city in which landline charges will begin. With the charges squared away, the message is delivered to the communication center for transmission. After transmission two copies of the message with proper servicing data entered thereon are returned to the Radioman for filing and abstracting. The original of each message abstracted is forwarded to the Chief of Naval Operations (DNC), and a copy kept on file for reference. By now you know that traffic routing and filing may vary somewhat on different ships. So, don't take this for the final word in internal handling of commercial traffic.

The expression "Chief of Naval Operations (DNC)" rates a word. You've already been introduced to this term but let's review its meaning. This simply means that DNC (Director, Naval COMMUNICATIONS) functions under thet Chief of Naval OPERATIONS in Washington. DNC is an integral part of CNO organization. Official correspondence from DNC is "FROM: CNO" and DNC signs it as: "CNO, By Direction." Official correspondence concerning toll traffic goes to DNC, but it must go via CNO.

TOLL TRAFFIC AND THE RADIOMAN

You may be wondering how much a Radioman must know about classes of messages and toll traffic in general. All Radiomen—3 to chief—should have a sound knowledge of the classes of messages. They must be able to recognize the various classes, and handle them efficiently when routing traffic. Collecting tolls and forwarding ABSTRACTS (reports of tolls collected) are matters that concern the RM first class and the RM chief only.

Although this billet will generally be filled by a Teleman, Radiomen first and chief are required to know abstracting and accounting, and must be able to fill the billet when called upon. The methods of computing charges and filling out abstracts are discussed in the reminder of this chapter.

How much toll traffic can the Radioman expect to handle? This will depend upon your billet. At a large shore station—especially one open to commercial traffic—abstracting class D and class E traffic will be a frequent occurrence. Aboard ship you won't often process class D traffic. The small amount of class D traffic now handled by Navy ships nevertheless represents an increase over the amount of such traffic handled by ships before World War II.

CLASS E

Your main concern with shipboard toll messages is class E. You'll keep an NCS Fund and forward monthly abstracts of messages which your shipmates have sent. With this in mind, let's consider the kind of information which is acceptable for class E transmission.

Class E was set up so that Navy men at sea could communicate and receive information concerning personal matters without paying more than they could afford. Class E is a PRIVILEGE, and, in general, is used sparingly. Under ordinary circumstances subjects that are acceptable are: matters of life and death, or serious illness; matters of personal arrangements or important business, not of a recurrent nature; occasional greetings on important anniversaries. Subjects that are not acceptable include trivial or frivolous messages; messages of unnecessary length; ordinary congratulatory messages; and so forth.

HOW TO DRAFT CLASS E MESSAGES

Class E messages involving tolls are always transmitted over Navy circuits in naval plaindress form. The entire commercial form of the message is placed in the text of the naval form. The heading is the same as any plaindress normal headings:

NSS DE NUBP—NM—2ØØ93ØZ FM NUBP—TO NSS GR BT

Once the message is refiled with Western Union, this heading is replaced by commercial routing information. In naval form, the text of this message includes all of the following:

MSG CK 22 NL COMLE JOHN DOE 1234 ELL STREET CHICAGO ILL *EXPECT TO BE HOME ABOUT TEN NOVEMBER NOW ABLE TO WALK WILL ADVISE YOU EXACT TIME AFTER ARRIVAL IN STATES BILL DOE USS DULUTH*

As far as Western Union is concerned, the text begins with the word "expect." The toll charges on this message also begin with that word and include all words shown in italics above. The group count for Navy purposes is 36, but for commercial purposes the message carries a CK of 22. Note that BILL DOE (the signature) is transmitted free, but USS *Duluth* must be charged for.

Our example class E message would leave the ship in the following form:

NSS DE NUBP—NM—2ØØ93ØZ FM NUBP— TO NSS GR 36 BT MSG CK 22 NL COMLE JOHN DOE 1234 ELL STREET CHICAGO ILL EXPECT TO BE HOME ABOUT TEN NOVEMBER NOW ABLE TO WALK WILL ADVISE YOU EXACT TIME AFTER ARRIVAL IN STATES BILL DOE USS DULUTH BT K

When drafting a class E message be sure the indicator MSG is the first word of the text. Follow this with the commercial check (CK—) and the domestic service indicator. This indicator may be NL (night letter), DL (day letter) and so forth. The sender may not wish to pay for a full-rate telegram, so he will specify how he wants the message to go. Be sure to include this indicator, otherwise the message will go full rate. The danger here is that you may collect for a night letter, and neglect to put in the indicator. Western Union would handle it full rate, and the money you collected would not be enough to cover the charges.

The commercial indicator, COMLE, must be inserted in all messages which will be handled by Western Union. This will come after the service indicator, or, if no service indicator is used, after the CK. The use of X to separate the address from the text, or the text from the signature is optional. However, if it is used, it must NOT be counted in the check, and must be removed before the message is refiled with a commercial system.

The date-time group which usually follows the second $\overline{\text{BT}}$ in a naval form message, may be omitted in a class E. For one thing, if this date-time group should be transmitted over commercial lines, it would be charged for. This would force the sender to pay for unnecessary words. Numerals are counted five numerals to the word.

In the following example LCDR Door of the USS *Duluth* sends a class E message to Lieutenant Roe of the USS *Chicago*. There is no charge for this message.

NTEF DE NUBP—NM 29Ø935Z—FM NUBP—TO NTEF GR $\overline{\text{BT}}$ MSG LT ROE WILL YOU HAVE DINNER WITH ME TONIGHT AT 19ØØ LCDR DOOR $\overline{\text{BT}}$ K

There is no need in this message for a service indicator, a commercial indicator, or the CK. The signature, LCDR DOOR, is included as a part of the text. The message ending ("break" sign, and K) is the same one used for any message in naval form.

SERIAL NUMBERS

Every commercial message, including class E, carries a serial number (SRS) which is used in accounting ONLY. Every abstracting form requires the SRS number of the message entered in the first column. Although this number is written on each copy of each commercial message, it is never transmitted over a circuit. SRS numbers are continuous up to 10,000, after which, a new series begins. Incidentally, don't confuse the SRS with the station serial number (NR) which ships and stations put on outgoing messages. Only one STATION SERIAL NUMBER is assigned to a message; it is transmitted with that message, accompanying it to its final destination. A commercial message, on the other hand, receives a new SRS number at each station which handles it.

DELIVERY

Once you accept a personal message treat its contents the same as you would any other message. You are not allowed to condense or alter the message without the authority of the originator. Personal messages are forwarded and delivered as soon as possible. When delivery cannot be made, the office originating the message must be informed.

If the message is to be refiled with a commercial company, the address in the heading of the message cannot be changed without the originator's permission. Changing the address without permission could foul up the toll charges. For instance, you forward a message from NAM Norfolk via Western Union to Joe Doe in Cleveland, Ohio. You get word that Joe Doe now lives in Chicago. You cannot change the address because the charges from Norfolk to Cleveland are not the same as the charges from Norfolk to Chicago. If the message came to NAM from a ship, it would have to be returned via radio for the originator's action.

CLASS E RATES

To help you determine the charges on class E messages, Western Union has published special rates which apply only to class E. For your ready reference, rate tables are listed in communications Circular Letter 1–47. These rates apply only from the points shown at the head of each rate sheet to other points in the United States. The tables will tell you how much to charge for the first ten words and how much for each word thereafter. New letters are promulgated as rates change.

While Circular Letter 1–47 will give you the word on toll charges within the United States, it doesn't list rates outside the continental limits. Aboard ship you'll have to get these by using the international operating signal QSJ. The operating signal is sent to the naval shore radio station with which your ship is in contact.

EXAMPLE:

NBA DE NYSW $\overline{\text{INT}}$ QSJ FARFAN $\overline{\text{AR}}$

Here NYSW is asking Balboa the rate per word to Farfan in the Canal Zone. QSJ may be combined with GR to get the charge per message instead of the charge per word.

EXAMPLE:

NBA DE NYSW $\overline{\text{INT}}$ QSJ GR 18 FARFAN $\overline{\text{AR}}$

This message asks: "What are the charges from your station for 18 words to FARFAN?" The rates in the Canal Zone can be gotten from Radio Balboa, and those for Hawaii from Radio Honolulu.

When you figure the charges on a class E message, count all the words in the text and signature—except the name and rank of the sender. In the signature of every class E message the number of the Navy Post Office (or name of the activity or ship) where the message originated, must appear. This is classed as "extra matter" and the minimum charge is two words. That is, one extra word in the signature is charged as two, and more than one word is counted word for word. Remember the example class E message to John Doe in Chicago? The name of the sender wasn't charged for, but USS *Duluth* was charged for as two words.

After you have counted the words, go to the Western

Union rate tables and determine the charges. Count the tolls from the city where the message will be filed with Western Union to the destination. The rates are listed for full-rate fast telegrams. If the sender wants a day letter (deferred day service) or a night letter (overnight service) refer in JCI to the special tables for deferred service. The special tables will convert the full-telegram rates to day- or night-letter rates. You will find that the rate for a day letter is the same up to 50 words. For a night letter, the cost remains the same up to 25 words. If more than 20 words (day letter) or 25 words (night letter) appear in the message, additional charges are figured in GROUPS of words, not by individual word count. The instructions with the tables tell you how to count above the day- or night-letter minimum. A Federal tax of 25 percent must be collected on all class E traffic, on which there are charges.

ABSTRACTING CLASS E

When abstracting class E traffic you will use a form called Abstract of Class E Messages Sent. This form, shown in figure 180, is used by both ships and shore radio stations. When money is collected an additional form, Statement of Account (NCS 235), must be submitted to Chief of Naval Operations (DNC). Both reports are forwarded in duplicate, with a third copy retained for your files. They are sent in each month, and must be postmarked by the second day of the month following the one covered by the report.

When abstracts of class E traffic are forwarded, separate reports are made of traffic which was refiled with Western Union, and traffic which was NOT refiled with Western Union. Never combine the two in one report.

For the sake of an example, suppose your ship is steaming south toward Panama when the time arrives to forward the monthly abstracts. During the month, your ship has transmitted class E messages to the following

OPNAV-20-872 (6-45)

U. S. NAVAL COMMUNICATION SERVICE

SHEET NO. 1

ABSTRACT OF CLASS E MESSAGES SENT

U. S. S. FLYUMOFF CV-ØØ

DURING MONTH OF FEBRUARY, 1949

SIGNED A. J. ROTH *A. J. Roth* RM 1. U. S. N. ~~COMMUNICATION OFFICER~~ / NAVY MAIL CLERK.

FORWARDED APPROVED *G.R.M. Bligh* G.R.M. Bligh, Capt. U. S. N. COMMANDING.

SRS No.	DATE	ADDRESSEE	DESTINATION	STATION SENT TO (CALL LETTERS)	DO NOT USE	No. WORDS	CREDIT TOLLS		CREDIT TAX		DR. CASH	
155	3	Dora Wilson	Pittsburg, Kan.	NAM		10	$	72	$	18	$	90
157	4	Geo. Cattermole	Norfolk, Va.	NAM		10		20		05		25
		LEAVE ABOUT 10 SPACES										
156	3	Len Barber	Long Beach, Cal.	NSS		21	2	14		54	2	68
158	4	Wm. Kearns	Boston, Mass.	NSS		10		48		12		60
159	5	Dr. D. Cooke	Buffalo, N.Y.	NSS		12		55		14		69
161	8	C. M. Meily	Newville, Pa.	NSS		18		76		19		95
		LEAVE ABOUT 10 SPACES										
160	5	Mary Louise Gallen	Arlington, Va.	NAO		15		78		20		98
	Note	---- Serial numbers start with first class E message (#1) sent from ship and these numbers continue through 10,000 at which time they are again started with number 1.										
	Note	---- Message serial number 161 was given to RADWASHDC via RADBALBOA.										
	Note	---- Signature of either communication officer or navy mail clerk is used.										
							THESE COLUMNS MUST BALANCE					
				TOTALS			$ 5	63	$ 1	42	$ 7	05
				TOTALS BROUGHT FORWARD FROM SHEET NO.								
				GRAND TOTAL			$ 5	63	$ 1	42	$ 7	05

Figure 180.—Abstract of class E messages sent.

875609 O—50 (Face p. 380)

Navy shore radio stations: NSS (Washington); NAM (Norfolk); NAO (Charleston), and NBA (Balboa). (Refer to figure 180.) In all, eight messages were transmitted in the following order:

1. Class E via NAM.
2. Class E via NSS.
3. Class E via NAM.
4. Class E via NSS.
5. Class E via NSS.
6. Class E via NAO.
7. Class E via NBA.
8. Class E via NBA.

The first seven were refiled with Western Union. The eighth message went to Pedro Miguel, Canal Zone, and was handled by the Tropical Radio Co. To abstract these, make out two reports; the first to contain seven messages, the second only one message. Group the messages according to the shore radio station which accepted them. All NAM messages are placed together, all NSS are together, and so forth. Leave about 10 lines of space between the traffic for each station. If one sheet of paper won't hold all the traffic, use a second sheet. Grouping the messages in this manner changes the chronology of the SRS numbers, but that is of no importance.

Message No. 8 is abstracted separately and does not appear on the form in figure 180. The charges on this message were determined by QSJ. Make a note of this on your abstract, and on copies of the message.

With the report shown in the illustration you would send money payable to Western Union, BUT MAILED TO NCS. The check covering the tolls on message No. 8 would be made payable to the Naval Communication Service which, in turn, transfers the money to Tropical Radio Co.

Remember, ABSTRACTS MUST BALANCE. In the form Abstracts of Class E Messages Sent, the tolls and tax in the credit column must total the same as the cash in the DR CASH column. In figure 180 you can see that the amount of the tolls ($5.30), plus the amount of the tax ($1.33), equals the cash ($6.63) shown in the cash column.

The form NCS 235 (Statement of Account) is required by the General Accounting Office. This form is signed

NAVY DEPARTMENT
NCS Form No. 235
NAVSHIPS (250)
(Rev. 6-32)
Approved by the Comptroller of the Treasury Nov. 4, 1916

NAVY DEPARTMENT

NAVAL COMMUNICATION SERVICE

STATEMENT OF ACCOUNT

READ INSTRUCTIONS ON OTHER SIDE

Radio Station U.S.S. BLANK (DEØØØ) (Ship or station), for the month of April, 19 49

DR. CR.

RECEIVED		AMOUNT		PAID OUT		AMOUNT	
Charges on messages filed during current month		3.	54	*Refunds*			
Collections for Previous Months On messages previously reported on which no charge or a short-charge was made.				Month	Error Notice Ref. No.		
Month	Error Notice Ref. No.						
August '48	MGM-12-3Ø-48		64				
				Money order fee			Ø8
				R. P. Receipt Nos.			
				Remittance herewith: [redacted] Money order No. 42456			
				Dated 7 March 1949			
				Drawn on Postmaster Wash., D.C.		4	1Ø
TOTAL		$ 4	18	TOTAL		$ 4	18

U.S.S. BLANK (DEØØØ)
(Ship or station)

San Pedro, California
(Place of forwarding)

7 March 1949, 19 49
(Date of forwarding)

I CERTIFY that the above is a true statement of all moneys received and disbursed by me during the month shown at top of page on account of Naval Communication Service.

There is forwarded herewith the sum of Four dollars and ten cents [redacted]

John Doe, RM 1, U. S. N.,

Signature of [redacted] Radioman in Charge. [redacted]

TO CHIEF NAVAL COMMUNICATIONS.

(IN DUPLICATE)

Figure 181.—Example of Statement of Account, NCS Form 235.

and forwarded in duplicate, with a third copy retained for your files. (See fig. 181.)

The total of the debit (left) side must agree with the total of the credit (right) side of the statement. The item "Remittance herewith" must show only the ACTUAL MONEY FORWARDED. This is the amount for which your check or money order is drawn.

When you collect the wrong account of money on a message, NCS will send you an ERROR NOTICE. Observe that form 235 has two columns marked "Error Notice Ref." If you know your toll traffic, you won't have to use these. Otherwise, you fill them out as follows. If you didn't collect enough to cover the charges on a message, you get a SHORT COLLECTION notice. When you submit your next statement of account you enter the number of this notice, and the amount you are forwarding, in the error notice column on the left (debit) side of the form. If you collected too much money, you get an OVER-COLLECTION notice. You enter this on the right (credit) side of your next statement of account.

Incidentally, if you forward DNC more money than you should, DNC credits you with that amount, but does not refund the money. Instead, your over-collection notice gives you the authority to deduct that amount from your next statement of account. In that way, you can return the money to the sender without putting DNC to the trouble of making a cash refund.

If you don't collect enough money in 60 days to refund the amount over-collected, or if the person to whom you are to refund the money has been transferred, you will have to write a letter to DNC explaining the situation. Remember that all letters to DNC concerning commercial traffic are ALWAYS signed and forwarded by the commanding officer of your ship.

Another thing, if you receive a short-collection notice and are unable to collect the amount due from the sender (assume he has been transferred) DNC may, in any case, require payment. This means the Radioman or the CO must use personal funds.

You will always receive two copies of an error notice. One is to be signed and immediately returned to DNC. The other is placed on file in your ship or station.

DEPARTMENT OF THE NAVY.

(Read instructions on back of this form.)

NAVAL COMMUNICATION SERVICE.

ERROR NOTICE.

MGM 3-7-49

Errors in collection of charges on messages filed with the

Radio Station USS Blank (DE ØØØ) Month and year April 1949

SHORT COLLECTIONS.			OVER COLLECTIONS.		
SRS No.	Sender.	Amount.	SRS No.	Sender.	Amount.
2Ø12	SKI 25NL	.24			
	U S TAX	.Ø6			
	Total,	$ .30		Total,	

WESTERN UNION TELEGRAPH COMPANY CLAIMS THE ABOVE NOT INCLUDED IN YOUR APRIL 1949 SETTLEMENT

One copy must be acknowledged below and returned to Director.

USS BLANK (DE ØØØ) (Ship or station.) San Pedro, California (Place.) 24 May 1949 (Date.)

Received a copy this date.

John Doe

John Doe, RM 1 USN

Navy Mail Clerk or Electrician in Charge.

Figure 182.—Example of an NCS error notice.

Another item on form 235 which needs a note of explanation is the one marked "RP Receipt Nos.": RP means reply prepaid and does not concern you when handling class E. The full particulars of the RP will be explained in its place—under class D traffic.

FORWARDING COPIES OF MESSAGES

When you send in your abstract of class E traffic, a copy of each message must be sent in with it. Be sure to include full transmission data on copies of messages which you forward. Copies should be neat and legible—preferably TYPED. Arrange them in the same order as they appear on the abstract. Duplicates of the messages are retained in station or ship files for at least 18 months. When you make duplicates of class E messages, use a book of three message blanks. The original goes to DNC, one copy goes into the general file, and the third is retained in your own file of commercial traffic.

FORWARDING THE MONEY

Here's how you should have your money order or supply officer's check made out to send with your abstracts. For class E traffic to addressees within the continental limits of the United States for delivery by Western Union, have it made out payable to the order of Western Union Telegraph Company, Washington, D. C. For all other commercial traffic, make the check or money order payable to the order of Naval Communication Service. These checks and money orders are always forwarded to Chief of Naval Operations (DNC). You should never send a check or money order directly to Western Union.

When occasion arises to use a money order, be sure to have it drawn on the Postmaster, Washington, D. C. Credit for the money order is shown on form 235, as follows: "Money order fee ____." Postage stamps, private check or cash, CANNOT be accepted in lieu of a supply officer's check or money order.

NCS SERVICE FUND

The collection of money and the responsibility for abstracting class E messages is always the duty of a ship's Radioman. Should you be assigned to handle class E funds, there are a few things you need to know. To begin with, a bond isn't necessary. Another thing, the exact sum of money which you can accumulate depends upon the commanding officer of your ship or station. The Director, Naval Communications, however, says that you cannot keep more than $100 in your Naval Communication Service fund. To keep on hand more than this amount requires the permission of DNC. When the money you collect reaches $100, turn it over to your supply officer and get a receipt for it. Whether or not your fund reaches the maximum limit, you must still deposit your money with the supply officer at least once a week, keeping out enough money to make change. When the time comes to forward the money, get a supply officer's check (Treasury check) payable to NCS or Western Union Telegraph Co., as appropriate.

Always keep your NCS service fund separate from any other funds for which you are responsible. The communication officer will inspect your fund at least once each month.

CLASS D

Class D messages handled by the Naval Communication Service are commercial messages on which all tolls are paid, INCLUDING NCS CHARGES. With the exception of press messages, all charges must be paid in advance by the sender. Class D messages can be filed during peacetime by any person, whether in the naval service or not, at any Navy shore station OPEN TO COMMERCIAL TRAFFIC, and on board any Navy ship. Because of the class E privilege, class D messages are seldom sent by Navy men.

The procedure for accepting, and the steps taken to release a class D message are, in general, the same as those for class E traffic. If you are at a shore station which is NOT open to commercial traffic, you cannot accept a class D message for transmission. Refer the sender to the nearest commercial radio station. If you are at a shore station OPEN to commercial traffic, you still cannot accept any class D messages going to ships at sea when (such messages) must be routed through another coastal station before going to the ship. Again, refer the sender to the nearest commercial station.

A class D message which originates at, or is relayed by, a Navy ship or a Navy shore station is always kept in international form. This, as you'll readily recognize, means that the message is a radiotelegram. Toll charges on such a message are determined by a word count called radio/cable count. This same radio/cable count is used to determine charges on Government radiotelegrams which will be handled commercially over a part of their route.

To show you how to figure the radio/cable count of a message, reprinted below is an international form message. This is a Government message (class A), but it will serve as an example of radio/cable count.

NPG DE NCBL NR 26 USS MISSOURI CK 2Ø NL
GOVT 15 14ØØ $\overline{\text{BT}}$ (preamble)
GOVT NAVY JAMES JOHNSON 1227 EAST TENTH
ST. SANDIEGO CALIF $\overline{\text{BT}}$ (address)
YOUR LEAVE EXPIRES ON BOARD Ø8ØØ 2Ø MARCH
$\overline{\text{BT}}$ (text)
USS MISSOURI K (signature)

In the example above, no words are counted or charged for in the preamble. The service indicator NL GOVT (night letter, Government), in the preamble, is not charged for. In special cases these indicators appear in the address, and are then counted and charged for. Other than the preamble and the $\overline{\text{BT}}$'s, everything in a radiotelegram is counted and charged for. This includes all of the address, the text, and the signature.

The number of words in any message depends upon the sender. The message must, however, have a TEXT. If it contains only an address, it can't be accepted for transmission. On the other hand, a message does not have to carry a signature. When it does, it may be written by the sender in any form.

Punctuation is not transmitted in radiotelegrams unless specifically requested by the sender. In that case, it is included in the word count. If the message contains Roman numerals, these must be spelled out or changed to Arabic figures. There are no Roman numerals in Morse code.

Joint Communication Instructions lists several tables with numerous examples to show you how to count abbreviated, compound, and hyphenated words, proper names, and so forth. These tables are too extensive to be reprinted here. JCI will also give you the details for determining the radio/cable count of code and cipher messages.

SPECIAL TYPES OF CLASS D MESSAGES

In addition to the regular class D message, there are certain SPECIAL types also in use. Among the special types of messages is the RP (Reply Prepaid). In this type, the sender of the message pays in advance for the reply to his message.

A MULTIPLE MESSAGE is a special type with a single text, sent to two or more addressees. This is similar to a multiple address message in teletype. Note the use of the service indicator TM.

A PAID SERVICE MESSAGE (ST) differs from a regular service message inasmuch as it is requested by the sender or the addressee. It is charged for at regular rates and is handled as a regular class D message.

On all special types of class D messages, the service indicators are transmitted as the first word in the address, and are charged for in the check. If the indicators are spelled out in full, each word is counted in the check and charged for. For instance, if the abbreviated service indicator RP is sent REPLY PREPAID, it is charged for as two words. Since no item in the preamble is counted in the check, service indicators in the preamble are transmitted free of charge.

For a complete list of special type class D messages, see JCI.

CLASS D CHARGES

Tolls are collected on messages because handling charges are due to one or more of the following: A land radio station, a mobile (ship) radio station, a landline (such as Western Union) or a cable company. The rate per word charged by any particular ship or shore station can be had by using the international operating signal, QSJ. This will get the information for you. You will also receive QSJ's which you must answer. Always be careful when you prepare a reply to a QSJ. Here's what sometimes happens. A Radioman at a shore station gets a QSJ request from a ship. In reply he sends only his station's charge for the message. As a result the ship collects only that charge, and nothing for landline tolls beyond that station. This fouls the book every time.

When you answer a QSJ from a foreign ship, quote the charges in francs and centimes. The rate of exchange is based on gold francs: 5 francs to the United States dollar or 20 cents to the franc. It takes 100 centimes to make a franc.

The charges to be collected on class D messages can be figured out by adding together the separate rates per word: that is, the coastal-station charge, the ship rate, and the landline or cable rates. If there are relaying charges, add these.

If you have no other means of determing the rates, charge 8 cents per word for the ship rate, and 10 cents per word for the coastal-station rate. If it's a commercial message going from ship-to-ship, the toll amounts to the ship charge per word for EACH ship. When you have the rate per word for the entire distance the message is to travel, multiply by the number of chargeable words in the message.

Examples:

Here are the charges per word for a class D radiotelegram sent via Western Union from Chicago to the USS *Duluth*. The message is relayed to the *Duluth* by the radio station at Key West.

11 cents (Western Union charge from Chicago to Key West).
10 cents (Key West radio station charge).
8 cents (*Duluth* ship charge).
29 cents per word (radio/cable count).

The charges on a class D radiotelegram from the USS *Duluth* via the Key West radio station addressed to London would be as follows:

8 cents (*Duluth* ship charge).
10 cents (Key West radio station charge).
34 cents (Key West to London cable charge).
52 cents per word (radio/cable count).

ABSTRACTING CLASS D

All telegraph, cable, and radio companies follow the same general system of accounting. The system on which a message originates becomes responsible for all charges on the message. That system collects the complete tolls, and pays to the next connecting line its tolls, plus all tolls due forwarding lines. It works as a chain, each company taking its charges, and forwarding the remainder to other connecting lines involved in delivery of the message. The actual transfer and adjustment of funds between the Naval Communication Service and other systems is handled by the Director, Naval Communications in Washington.

CLASS D ABSTRACTING FORMS

We can wind up our discussion of abstract forms by considering the three forms used for abstracting class D commercial traffic. These are form NCS 200 (shore stations), forms NCS 233 and 234 (ships).

Shore stations use form 200 for abstracting all Government and commercial traffic received and sent forward, or delivered. This form is filled out in duplicate, the original going to DNC and a copy for your station files. It must be postmarked not later than the second day of the month following the month covered by the abstract. If an error notice is received, be sure to correct your file copy accordingly.

Study the sample form shown in figure 183. In each case the column heading explains the data to be entered.

Form 233 is used for all toll messages SENT by a ship. The proper way to fill out this form is shown in figure 184. The procedure for forwarding, the number of copies forwarded, and the entry of error notices in file copies is the same as for form 200. Special attention should be given columns headed CREDIT and DEBIT. The first column under credit requires entry of tax collected on the messages. The second is headed Navy, so you'll enter here any tolls that are due NCS and all connecting systems. The columns following are blank. Here you enter the names of any connecting systems which are entitled to a share of the tolls. If NCS has money coming from another system, the name of the system and the amount of the money will be entered in one of the debit columns.

All commercial messages RECEIVED on board ship or relayed should be entered on form 234. This form is also filled out in duplicate and forwarded to DNC by the second day of the month. Since both NCS 233 and

NCS 234 are shipboard forms, there is always a possibility your ship will be at sea on the second day of the month. In this case, be sure your reports are POSTMARKED by the second. You'll note that the sample form shown in figure 185 contains two relayed messages. The letter R appears after the SRS number on each of these. Regardless of which form you have filled out for abstracting toll traffic, always correct the file copy if an error notice is received.

This introduces you to all abstracting forms in use by the Naval Communication Service. You'll find that the three forms just discussed are also submitted when abstracting press and Government traffic.

Before leaving the subject of class D abstracting, let's reconsider briefly form NCS 235. This, you'll recall, is the statement of account which must be forwarded whenever money has been collected. You will submit this form with the class D traffic on which you have collected tolls.

Now, turn back for a glance at the statement of account (fig. 181), and we'll clear up the matter of RP notices. If a part of your collections has been made in the form of RP (reply prepaid) receipts instead of cash, attach these RP receipts to your abstract when you mail it. In order to make your statement of account balance, make a separate entry of RP receipts. Place this entry on the credit side of the statement as follows: "RP receipt No.——. $——."

Other details concerning RP's can be squared away with an example. Assume, for instance, a message is received addressed to John Doe with the prefix "RP $3.20." John Doe should be given an RP receipt for $3.20. If he sends a reply within 90 days, his RP receipt should be accepted and applied as payment of the charges on his reply. If the charges on his reply are greater than $3.20, he would have to pay the difference in cash. The amount, $3.20, is entered opposite the receipt number

DEPARTMENT OF THE NAVY
Bureau of Ships
NCS-200—(20M—7-1-41)
Form approved by the Comptroller of the Treasury February 20, 1915

Restricted

SHEET NO. 1

ALL GOVERNMENT AND COMMERCIAL MESSAGES RECEIVED FROM ALL LAND LINES, CABLES, SHIPS, OR STATIONS AND SENT FORWARD OR DELIVERED SHOULD BE ENTERED ON THIS FORM

U. S. NAVAL COMMUNICATION SERVICE

ABSTRACT OF ALL COMMERCIAL MESSAGES RECEIVED AND SENT FORWARD, OR DELIVERED, AT BALBOA RADIO (NBA) STATION DURING THE MONTH OF OCTOBER, 1949

FORWARDED OCTOBER 19 49 John Doe, U. S. N., RADIOMAN IN CHARGE

SRS. NO. (1)	DATE (2)	OFFICE OF ORIGIN (3)	TRANSMITTING DATA: REC'D FROM (4)	TRANSMITTING DATA: SENT TO (5)	ADDRESSEE (6)	DESTINATION (7)	DO NOT USE THIS COLUMN (8)	NO. OF WORDS (9)	THIS STATION CHARGE (10) NBA	Charges beyond: Navy (11)	RMCA (12)	AAC (13)	TRT (14)	PNT (15)	MRT (16)	MISC DUE TO: (17)	TOTAL AMOUNT DUE (21)	Charges due U.S.N.C.S. from: Navy (22)	RMCA (23)	AAC (24)	TRT (25)	PNT (26)	MRT (27)	MISC DUE FROM: (28)	CASH (31)
	Oct.																								
9584	1	Camosun/VGPF	Canada	PNT	Fernie	Balboa		6	.60					.12			.72							.72 Canada	
9585		Saucor	Owner	AAC	Gulf Oil	Barranquilla, Colombia		12	1.20			2.16					3.36							3.36 Owner	
9586		Vicksburg/KVBP	"	PNT	Standard Oil N.J.	Balboa		16	1.60					.32			1.92							1.92 "	
9587		Monmouth/KFLF	"	TRT	Fernie	Cristobal		28	2.80				.56				3.36							3.36 "	
9588		Kashirstroi/UOBG	Russia	PNT	Payne & Wardlaw	Balboa		22	2.20					.44			2.64							2.64 Russia	
9589		Beaver Victory/ANOA	Owner	"	Norton Lilly	"		13	1.30					.26			1.56							1.56 Owner	
9590		Glenpark/GCBB	G.B.	TRT	Fernie	Cristobal		17	1.70				.34				2.04							2.04 Great Britain	
9591	2	Boonesborough/ANWS	RMCA	PNT	"	Balboa		14	1.40					.28			1.68		1.68						
9592		Vincenzia/HPLV	Panama	TRT	Fenton	Cristobal		6	.60				.12				.72							.72 Panama	
9593		Orotava/HRAV	Honduras	"	UniFruit	"		9	.90				.18				1.08							1.08 Honduras	
9594		Chirripo/HRBU	"	"	"	"		11	1.10				.22				1.32							1.32 "	
9595		Queen of the Seas/AOBD	Owner	AAC	Grace	Buenaventura, Colombia		21	2.10			3.78					5.88							5.88 Owner	
9596		Balboa	Sender	RMCA	Master	Pennsylvania Sun/WNKC		25	2.50		2.00						4.50								4.50
9597	3	Balboa	"	Norway	"	Brajara		25	2.50							2.00 Norway	4.50								4.50
9598		"	"	Owner	"	Ocala/VICTORY/ANEF		12	1.20							.96 Owner	2.16								2.16
9599		"	"	"	"	William Whipple/KFVI		40	4.00							3.20 "	7.20								7.20
9600		Chapultepec/KOOB	Owner	AAC	Barber Asphalt Co.	New York, N.Y.		29	2.90			5.80					8.70							8.70 Owner	
9601		Orotava/HRAV	Honduras	TRT	UniFruit	"		20	2.00				4.00				6.00							6.00 Honduras	
9602		Chirripo/HRBU	"	"	"	Cristobal		9	.90				.18				1.08							1.08 "	
9603		Argual/HRAY	"	"	"	"		13	1.30				.26				1.56							1.56 "	
9604		Surprise/KEWJ	Owner	"	Panaco	"		12	1.20				.24				1.44							1.44 Owner	
9605		Wm. G. Warden/WSCD	"	"	Stanship	"		20	2.00				.40				2.40							2.40 "	
9606		Penna. Sun/WNKD	RMCA	PNT	"	Balboa		10	1.00					.20			1.20		1.20						
9607		Ocala Victory/ANEF	Owner	"	Andrews	"		7	.70					.14			.84							.84 Owner	
9608		Wauhatchie/ANCH	"	"	Payne	"		10	1.00					.20			1.20							1.20 "	
9609	4	Balboa	Sender	Owner	Master	Esso Wilmington/KFFM		32	3.20							2.56 Owner	5.76								5.76
9610		Shamrock/WQBI	Army	AAC	Sup't. Water Division	Los Angeles, Calif.		24	--			5.76					5.76							5.76 U.S. Army	
9611		Charles Bulfinch/KIAC	Owner	TRT	Wilford McKay	Cristobal		16	1.60				.32				1.92							1.92 Owner	
9612		Ena/PDXQ	Netherlands	"	Andrews	"		8	.80				.16				.96							.96 Netherlands	
9613		William Whipple/KFVI	Owner	PNT	Norton Lilly	Balboa		41	4.10					.82			4.92							4.92 Owner	
9614		Archibald R. Mansfield/KSNF	"	"	Wilford McKay	"		72	7.20					1.44			8.64							8.64 "	
9615		Manassas/KVKZ	"	"	"	"		20	2.00					.40			2.40							2.40 "	
9616	5	Balboa	Sender	Owner	Master	Kyle V. Johnson/WSGL		24	2.40							1.92 Owner	4.32								4.32
9617		Albert E. Watts/WHSX	RMCA	TRT	Wilford McKay	Cristobal		31	3.10				.62				3.72		3.72						
9618		Robson Nacella/GBBY	G.B.	"	Andrews	"		10	1.00				.20				1.20							1.20 Great Britain	
9619		Empire Salisbury/GJMQ	"	"	"	Colon		15	1.50				.30				1.80							1.80 "	
9620		Chirripo/WHBU	Honduras	"	UniFruit	New Orleans, La.		10	1.00				2.00				3.00							3.00 Honduras	
9621		Bethore/KDWW	RMCA	PNT	Panaco	Balboa		7	.70					.14			.84		.84						
9622		John A. Dix/KKFV	Owner	"	Wilford McKay	"		68	6.80					1.36			8.16							8.16 Owner	
9623		Trinidad Head/KXVC	"	"	Norton Lilly	"		16	1.60					.32			1.92							1.92 "	
9624		Balboa	Sender	Owner	Master	Esso Patersen/KFGF		14	1.40							1.12 Owner	2.52								2.52
TOTALS									79.10		2.00	17.50	10.10	6.44		11.76	126.90		7.44					88.50	30.96

16—23571-1 INSTRUCTIONS.—To be in duplicate: original forwarded to the office of the Director Naval Communications, Washington, on the second day of each month for the preceding month; duplicate to be placed in the station's files. Station copy should be corrected immediately upon receipt of notice of errors from Director.

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Figure 183.—Naval Shore Radio Station Form NCS 200.

-4 Naval Shore Radio Station Form NCS 200 on your statement. The cash is included with the other cash collected in the item "Remittance herewith." If, on the other hand, the charges on the reply amounted to only $2.40, make a memo to this effect on the bottom of the RP receipt forwarded with your monthly statement. When a person fails to use all the money allowed him for a reply in an RP receipt, the adjustment is made at the other end. The original sender—within 3 months of the day the RP was issued—can request a refund of the difference from the originating commercial communication system. However, the difference must be at least forty cents ($0.40). When accepting an RP receipt, never, under any circumstances, refund the difference between the RP voucher and the tolls involved. That's a matter for the original sender to square away.

FORWARDING COPIES, CLASS D

When you send in your abstracts of class D traffic be sure to include a typewritten copy of each message, just as you did for class E. The original goes to DNC; one copy goes into the ship or station files, and one is retained in your file of commercial traffic.

Besides duplicating the original message, there is other information which must be included. Make a note on the copies of any discrepancies in counting words, any delays exceeding one hour, and any charges collected. Also, if acknowledgment or receipt of the message was requested but not received, make a note of this for future reference should the matter arise.

UNITED STATES GOVERNMENT TAX

When you collect the charges on a message, you must also collect the Government tax. The amount of the tax is figured according to the TOTAL charges for the message. This tax applies to messages in the United States, Hawaii, and Alaska. It includes, as you know, any class E message which is refiled with a commercial company.

You collect 25 percent on amounts paid in the United States for messages going to points in this country, and for messages between points inside the United States and Alaska or the Hawaiian Islands. You collect 10 percent on amounts paid in the United States for telegraph, cable, and radio messages to and from Canada, Mexico, and other points outside the United States (of course, this does not include Alaska and the Hawaiian Islands). You collect 10 percent for a radio message from a shore station to a commercial ship.

When you forward the money, include tax and tolls in one money order or one supply officer's check. Indicate on form 235 the total tax as a separate item. (See fig. 182.)

No tax is collected on Government messages, press messages, or ship-to-ship messages transmitted direct.

PRESS

Press messages are a form of class D commercial traffic. Press representatives are allowed to send their messages from naval ships either through Navy shore radio stations or commercial radio stations. Any Navy shore radio station—whether open to commercial traffic or not—will accept press dispatches providing commercial facilities are not available. To avoid competition with commercial companies, the Navy forwards ship-to-shore press messages through commercial radio stations whenever possible.

If you have occasion to handle press traffic from a ship to a commercial radio station, always mark the messages paid, though normally you won't collect any money. This is done because collect radio traffic can't be sent through a COMMERCIAL radio station. The charges on the messages you have marked paid will be collected by DNC in Washington.

Press dispatches may be sent collect when they go from a ship to a Navy shore radio station. In this case, they must be marked collect. DNC bills the newspaper service for the Navy's portion of the tolls. The landline charges after the dispatch gets to the beach, are collected at the destination by the commercial company concerned.

In the following example a paid dispatch is sent DPR (Day Press Rate) from the cruiser *Duluth* to the *Los Angeles Examiner. Duluth* gives the message to the commercial radio station KSE at Torrance, Calif.

KSE DE NUBP NR 1 USS DULUTH CK 216 DPR PAID 1Ø Ø93Ø $\overline{\text{BT}}$ DPR EXAMINER LOS ANGELES CALIF $\overline{\text{BT}}$ TEXT TEXT TEXT TEXT ETC.

The above message is in international form. Note that the indicator DPR appears in both the preamble and the address. It is counted and charged for in the address, but not in the preamble.

Press messages received by a naval radio station within the continental limits of the United States from a Navy ship must be given to a commercial landline company for transmission to their destinations.

ABSTRACTING PRESS

Press messages are given regular SRS numbers, with the capital letter P after the number—for example, SRS 116P. Ship abstracts are made on form NCS 233 and shore station abstracts on form NCS 200.

Be particularly careful when you abstract press dispatches. Be sure to include copies of the dispatches with your abstract. Enter all transmission data in the proper columns. (See fig. 184.) In the remarks column of form NCS 233 write the name of the press association or newspaper to which tolls are chargeable. Since form NCS 200 has no remarks column, write the name of the press association or newspaper from which money is due, at the head of one of the columns marked "Charges Due U. S. Naval Communication Service From—." In this column enter the amount due.

There is one factor which sometimes makes the handling of press dispatches from aboard ship easier. When newspaper correspondents are on hand to cover a naval operation, arrangements for handling press messages are usually worked out in advance. Your communication officer will normally make the arrangements before the operation begins. Thus, the complete burden of clearing press traffic will not rest upon the ship's Radioman.

GOVERNMENT MESSAGES

Any tolls on a Government message (class A or B) are paid from a Government fund. The Naval Communication Service never charges for handling these messages; the charges are made by commercial companies or connecting systems. Charges are made at regular commercial rates, or, in some cases, at special Government rates.

Radiotelegrams originated by Government officials are never forwarded with charges COLLECT. Instead, they are handled as if they were PAID messages. At the end of the month these messages are abstracted and the accounts forwarded to DNC.

So there will be no mistake as to which Government department must pay the tolls, messages contain special abbreviations which appear as the first two words in the address. You are already familiar with one of these abbreviations: GOVT NAVY. A message of the Department of Justice carries GOVT JUS; from the Treasury Department, GOVT TREAS; and so forth.

Government traffic originating at a Navy radio station (ship-to-shore) is not charged for until transferred to a commercial line. The abstracting is done by the station which transfers. However, traffic originating on a ship and relayed to another ship before going to a commercial

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ABSTRACT OF MESSAGES SENT
OPNAV-20-233 REV. 9-48

INSTRUCTIONS
For detailed instructions refer to DNC-5, Appendix III; Section B.

REPORT SYMBOL (OPREP-20-35)

U.S.S.	FOR MONTH OF	SIGNATURE (~~XXXXXXXXXXXXXX~~ Navy Mail Clerk)	SIGNATURE (Approving Officer)	
BLANK (DE000)	April, 1949	Richard Roe (signature) Richard Roe, RM 1 U.S.N.	John Doe (signature) John Doe, Captain U.S.N.	SHEET 1 OF 1 SHEETS

SRS NO.	DATE SENT	ADDRESSEE	DESTINATION	TRANSMITTING DATA (Use call letters only) SENT TO	RELAYED VIA	DO NOT USE THIS COLUMN	NO. OF WORDS	CREDIT SENDING CHARGE (Ship Tax)	NAVY						DEBIT		CASH	REMARKS
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
2431	3	Smith	Chicago, Ill.	NAM			8		.60					.60			.66	
2432	3	Baker	SS Sky Plow	WZZX			9				.72						.72	
2433	4	Blakenship	SS Sea Hill	WXZX			10			1.75							1.75	
2434	4	Greenamyer	SS Smithville	WPQQ			8			1.50							1.50	
2435	4	Associated Press	New York	NSS			75DPR											Sender: John Smith Assd. Press
2436	7	Registar	Sanfrancisco	WSA			10	.80		2.10					2.90			

J.V. NO.												
AUDITED	TOTALS	$ .80	.60	5.35	.72			.60	2.90		4.63	
BILLED	TOTALS BROUGHT FORWARD FROM SHEET NO. ____	$										
FILED	GRAND TOTALS	$ .80	.60	5.35	.72			.60	2.90		4.63	

B-0065

Figure 184.—Shipboard form NCS 233.

Restricted

875609 O—50 (Face p. 394)

ABSTRACT OF ALL MESSAGES RECEIVED AND DELIVERED ON BOARD OR RELAYED

OPNAV-20-234 REV. 9-48 REPORT SYMBOL (OPREF-20-36)

INSTRUCTIONS - Relayed messages are not charged for by Naval Communications Service; hence, relayed messages should have entries only in columns 1 to 8, inclusive, and in column 10. Place letter "R" after SRS number on relays. Ship's file copy should be corrected upon receipt of notice of errors. For detailed instructions refer to DNC-5, Appendix III, Section B.

U.S.S.	FOR MONTH OF	SIGNATURE (Communication Officer - Navy Mail Clerk)	SIGNATURE (Approving Officer)	SHEET
SABINE/NAKF	April, 1949	Albert Jones (signed) Albert Jones, RM 1 U.S.N.	Homer Polk (signed) Homer Polk, Captain U.S.N.	SHEET 1 OF 1 SHEETS

SRS NO.	DATE RECD.	OFFICE OF ORIGIN	ADDRESSEE	DESTINATION	RADIO STATION RECEIVED FROM (Call letters)	RADIO STATION SENT TO (Call letters)	NAME OF COASTAL STATION ROUTED VIA	DO NOT USE THIS COLUMN	NO. OF WORDS	THIS SHIP RECEIVING CHARGE	AMOUNT R.P.	CHARGES DUE NAVAL RADIO SERVICE FROM: NAVY						REMARKS
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
31	14	TexasCity	USS SABINE	NAKF	WPA		Port Arthur		26	2.08			2.08					
32	22	Portland	USS SABINE	NAKF	NMF		Boston CG		19									
33	22	Portland	USS SABINE	NAKF	WAG		Rockland Me.		12	.96				.96				
34	25	New York	USS SABINE	NAKF	WNY		New York		28	2.24			2.24					
35	28	New York	USS SABINE	NAKF	WNY		New York		10	.80			.80					
36R	29	New York	USNT MUIR-WOODS	NDPY	WNY	NDPY			15									
37R	29	New York	USNT MUIR-WOODS	NDPY	WNY	NDPY			10									

J.V. NO.			11	12	13	14	15	16	17	18	19
	AUDITED	TOTALS	$ 6.08			5.12	.96				
	BILLED	TOTALS BROUGHT FORWARD FROM SHEET NO. ______	$								
	FILED	GRAND TOTALS	$ 6.08			5.12	.96				

Fig. 71

B-6067

Figure 185.—Example of form NCS 234.

line is always reported by the first ship—NOT the ship that turns it over to the commercial line.

When a Government message requests or requires an answer, the answer is transmitted at no cost to the person sending it. This is true even if there is no naval communication office at the point where the reply is filed. The reply (say by a Navy employee) will be sent at full commercial rates as a GOVT NAVY COLLECT—the Government, not the sender, pays the charges. Assume that Richard Roe, a civilian employee of the Navy Department is stationed on an island in the south Pacific. The island has commercial communication facilities, but no Navy communication office. Roe receives a message from the Navy Department which requests a reply (or obviously needs a reply). He sends the answer over commercial lines as a GOVT NAVY COLLECT. It costs him nothing. On the other hand, if Roe originates a message to the Department on his own, he must pay all commercial charges.

FILING TRAFFIC

When Government traffic is filed with your station and no class of service is specified, your CWO will determine the class of service—day letter, night letter, etc. He will normally send it by the cheapest method consistent with the precedence of the message.

Overseas traffic originating at points within the United States may be filed with a local naval communication office, or with a landline or cable company. Let's assume that a message originates in Albany, N. Y., bound for Belize, British Honduras. It would be filed with Western Union at Albany, addressed "Govt Naval Communications, New York City." The first part of the text reads "For (Government Agent) Belize, British Honduras." Charges are paid by the originating office from Albany to New York City. The naval communication office, New York, puts the message in the Naval Communication

System at this point. It would then be transmitted free of charge to Balboa, Canal Zone. At Balboa it is transferred to Tropical Radio for transmission to their station at Belize for delivery. The Naval Communication Service would pay Tropical Radio the tolls due on this message. NCS would later collect these charges from the Government department which originated the message. The Government agent at Belize could send his answer to Albany via Tropical Radio and the naval radio station at Balboa.

A person filing a message for a branch of the Government must be able to prove that he is authorized to do so. He is required to furnish full identification, as well as information needed to bill his office, should there be any charges for transmission over commercial lines.

At some stations you'll find that messages are frequently filed over the telephone. In like manner, final delivery is sometimes made by phone. Always check these dispatches carefully. When receiving a dispatch by phone, read it back as a double check. Any time you make final delivery of a message over the phone insist that the message be read back to you.

OUTSIDE THE CONTINENT

It's impossible to set up definite rules for the routing of Government mesages originating OUTSIDE THE CONTINENTAL UNITED STATES. Usually the path of transmission of such messages is the most economical possible from the standpoint of toll charges. The situation will vary according to the location of the overseas activity. When a Government department has a representative near a Navy overseas radio station, traffic to and from the representative is channeled through the Navy radio station. When the representative files a message with the Navy station he pays in advance the commercial tolls from his office to the Navy station.

It isn't always cheaper to have your traffic from outside the United States relayed by a Navy radio station. It is sometimes less expensive to send a message all the way to the United States by commercial cable, rather than part way by cable and the remainder by Navy radio. In general, this is due to the fact that cable companies will not allow special Government rates unless the traffic is going directly to or from the United States on their cable. When this situation arises, always contact the local cable office to get the rate information.

The Naval Communication Service is also available for handling official Government traffic between certain points within the United States continental limits. Usually this traffic is between Government departments and their field offices. When a field office files a message with a Navy station, the commercial charges from the field office to the Navy station must be paid in advance. On traffic coming the other way—from the department to the field office—the commercial tolls are paid by the Naval Communication Service. NCS then bills the department. The traffic is handled by the Navy (or Army or Coast Guard) to the naval radio station nearest the field office. At this point it is transferred to commercial lines.

There are occasions when you will have to put a complete naval form message in the TEXT of a commercial form message. If there are call signs in the naval form message which are PRONOUNCEABLE, write them as they are. For instance, the call sign NULT would be written NULT. If, on the other hand, the call sign is not pronounceable, write it using the phonetic alphabet. NUBP would be written NAN UNCLE BAKER PETER.

Messages in international form handled on naval circuits always use radio/cable count. The domestic count is used only when messages are forwarded to a domestic company for delivery to points in the United States, Canada, or Mexico.

Naval messages in international form get a new POINT OF ORIGIN when they are refiled with a domestic system.

The original point of origin is added to the signature by the station refiling. As an example, let's look at a message sent by Radio Washington to Radio San Francisco and transferred to Western Union at San Francisco. Washington is shown in the heading as the original point of origin.

NPG DE NSS NR 168 P WASHINGTON DC CK 21
GOVT Ø3 1720 $\overline{BT}$ (heading)
BUREAU OF SHIPS K (signature)

When the message is transferred to Western Union, San Francisco becomes the new point of origin.

NR CK 12 GOVT SAN FRANCISCO CALIF 455 P
APRIL 3 (heading)
BUREAU OF SHIPS WASHINGTON DC (signature)

The addition of two words in the signature of our example message would be charged for by Western Union.

ALASKA AND PANAMA

A word should be said here of Government messages in Alaska, and those of the Panama Government handled by NCS. Navy radio stations in Alaska handle GOVT NAVY messages, but do not handle traffic for other departments of the Government. Messages for other departments are passed to the nearest Army station.

The Naval Communication Service does not charge for official messages sent and received for the Panama Government.

ABSTRACTING GOVT MESSAGES

Ships

Aboard ship, Government messages are abstracted on one of two forms: NCS 233 or NCS 234. The form you will use depends upon whether the message was sent by your ship or received by it. Form 233 is used for outgoing Government messages and form 234 is used for those received and delivered on board, or RELAYED by your ship. The forms and the procedure you'll recognize are the same used for incoming and outgoing shipboard class D traffic.

When a Government message goes from your ship to a Navy shore radio station you make no report of it. The abstract is made out by the shore station.

If, on the other hand, your ship sends a Government message to another system—commercial or foreign—a report of it is made on form 233. The message is given a regular SRS number followed by the letter G. Two copies of this message is forwarded to Chief of Naval Operations (DNC).

Government radiotelegrams received aboard from a Navy ship or a Navy shore radio station are handled free of charge. You make no report of these.

When a message comes aboard from outside the Naval Communication Service it must be reported on form 234. Two copies of the message are forwarded to CNO with the abstract. Make no entry in column 11 of form 234 headed: "This ship receiving charge." This is a Government message, so your ship won't charge for receiving it.

ABSTRACTING GOVT MESSAGES

Shore Stations

Government messages transferred to commercial lines by a Navy shore radio station are abstracted on NCS form 200. This is the same form used by shore stations for class D traffic, but Government and class D messages are not abstracted in the same report. Reports of Government messages are made independently of regular commercial messages on a form 200 marked Government. Copies of all Government messages, original and carbon, are mailed with the abstract to DNC by the 10th of the month following the month during which the traffic occurred. A separate series of SRS numbers are maintained for Government traffic, a new series being used for every 10,000 messages.

When a shore station forwards a message to a commercial ship, this message is also abstracted on form 200. The Government department originating the message is responsible for the commercial ship's charge for receiving that message. NCS collects these tolls, meantime crediting the ship of destination (foreign government or commercial company, depending upon who owns the ship) with the charges.

REFUNDS

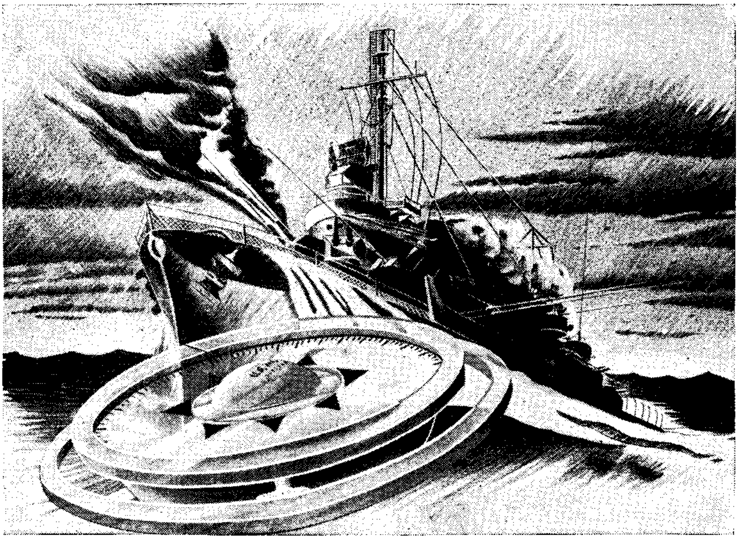
Once a message has been sent, the only way the sender can be refunded his money is through the Chief of Naval Operations (DNC). At your ship or station you can refund the money to the sender only if you were unable to get the message through. This assumes, of course, a break-down in the system—cable break, landlines down, ship out of range, and so forth. When this is the case, you forward the message to DNC with an explanation on the message form showing why it was canceled. Such a canceled message would nevertheless bear an SRS number.

You should understand that no refund can be given for nondelivery of a radiotelegram due to such reasons as ADDRESSEE UNKNOWN, ADDRESSEE DECEASED, ADDRESSEE NOT ABOARD SHIP, ADDRESSEE LEFT TOWN, and similar causes. In such cases the service has been properly performed, and no refund can be made.

QUIZ

1. What is the meaning of the indicator COMLE? Where is it used?
2. How does the SRS number on a commercial message differ from the NR number on a radio message in naval form?

3. Western Union rate tables list charges for what type of service?
4. In collecting tolls, what items are not counted in the signature of a class E message?
5. How can you determine the charges on a day or night letter?
6. What form is used for abstracting class E traffic?
7. In what order are shipboard class E messages arranged on the abstract form?
8. When is form NCS 235 forwarded with an abstract?
9. In what form may collections be forwarded to DNC?
10. When tolls are due Western Union, to whom is the supply officer's check (or money order) made payable? To whom is it forwarded?
11. What is an error notice? What are the two types of error notices?
12. Two copies of an error notice are always received when tolls are in error. What action is taken on each copy?
13. What is the maximum amount of money allowed to accumulate in the NCS fund before it is turned over to the supply officer?
14. In what form are radiotelegrams and cablegrams always sent?
15. Forms 233 and 234 are used for abstracting shipboard class D traffic. Which is used for incoming traffic, and which for outgoing?
16. What three types of messages go tax free?
17. What is the class of a GOVT NAVY message?
18. When a naval form message is placed in the text of a commercial message, in what form are call signs transmitted?



CHAPTER 14

NAVIGATION

SAFETY OF THE SHIP

Ordinarily, navigational duties concern only the navigator and Quartermaster. But, in some emergencies, the Radioman must share their responsibilities. This chapter supplies a description of elementary phases intended to qualify the Radioman who finds himself assisting the navigator when the occasion demands. All steps explained here are described in much greater detail in Mixter's *Primer of Navigation,* and in Dutton's *Navigation and Nautical Astronomy.*

SCIENCE OR ART

Navigation is the art or science of determining a ship's position at any time, and of conducting a ship from one position to another. Generally speaking, navigation may be divided into two parts: celestial and piloting. Celestial navigation is the determination of a ship's position with the aid of celestial objects, such as the sun, moon, stars, and planets. You're probably already familiar with piloting, the art of determining the ship's position with the aid of buoys, lights, and various landmarks. This is the phase of navigation that concerns you most.

PILOTING REQUIRES VIGILANCE

It is obvious that a ship hundreds of miles from land is fairly safe even though the navigator has made a slight error in celestial observations to determine his fix. Normally, there is time to correct the error before the next landfall. But in piloting the story is different. A ship can be aground in 30 seconds if she takes the wrong course while steaming in a narrow channel. There's little or no time to correct errors. Thus, you can see that piloting demands constant vigilance, alertness, and a thorough knowledge of the principles involved.

Two essential actions must be performed in piloting. First, the position of the ship must be fixed accurately. Next, the proper course to steer must be determined.

THE MAGNETIC COMPASS

The compass is the basic instrument for all navigation. There are two types—the gyrocompass and the magnetic compass. The gyrocompass is a mechanical device that depends on an intricate mechanism for its operation. The magnetic compass depends on no outside force, other than the earth's magnetic field.

Even though your ship is equipped with a gyrocompass, you must understand the magnetic compass. You will have to rely on it whenever the gyrocompass fails. By understanding the workings of the magnetic compass, you can check the operating condition of the gyrocompass.

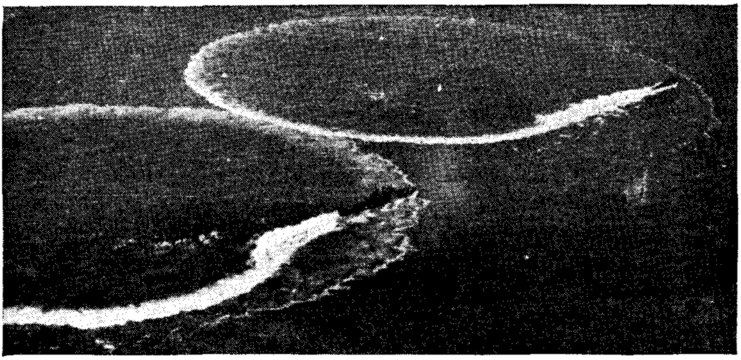


Figure 186.—Ships maneuvering.

The design of the magnetic compass is fairly simple. The heart of the instrument is a 7½-inch compass card. Four magnets, parallel to the north-south line of the card, are attached underneath. The card and its magnets are supported by a jeweled pivot. There is very little weight on this pivot because the card is resting in a solution of alcohol and water. The card and the solution are sealed in a bronze bowl which is watertight and completely filled. The lubber's line is painted inside the bowl, and the bowl is suspended from gimbal rings to minimize the effect of the roll and pitch of the ship. The compass is mounted in the binnacle which is fitted with magnets for countering the magnetic effect of the ship on the action of the compass.

VARIATION

Around the earth, a magnetic field exists between the north and south magnetic poles. Any other magnets in the earth's field tend to line up with the lines of force in this magnetic field, just as an anchored ship will head into the wind and tide. Since the magnetic poles do not coincide with the geographic poles the compass does not point to true (geographic) north. Thus, the direction in which the compass points is known as magnetic north.

The difference in direction between magnetic north and geographic north is called VARIATION.

In figure 187, let N equal true north, and M equal magnetic north from position X. Then XN is the true north direction, XM is the magnetic north direction, and NXM is the variation for the locality. If, as in this case, magnetic north is eastward of true north, the variation is called easterly, and is marked (E). If the magnetic north direction is westward of true north, the variation is called westerly and is marked (W).

When the earth's magnetism acts upon the magnetic compass, the north magnetic pole attracts the north-seeking ends of the magnets of the compass card and

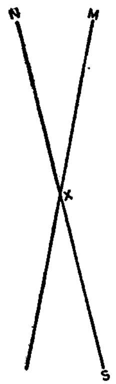


Figure 187.—Variation.

the south magnetic pole attracts the south-seeking ends. In this way, the axis of the compass card coincides with the magnetic field, with its north end in the general direction of the north magnetic pole. When this has occurred, the north point of the compass card is eastward of true north, if the variation is easterly. If the variation is westerly, the north point of the card will be westward of true north.

DEVIATION

Iron and steel ships have marked magnetic qualities and their magnetism affects the compass so that the axis of the compass card does not coincide with the axis of the earth's magnetic field. This is known as DEVIATION. (See fig. 188.) It is partly, but not completely, counteracted by the compensating magnets located in the binnacle.

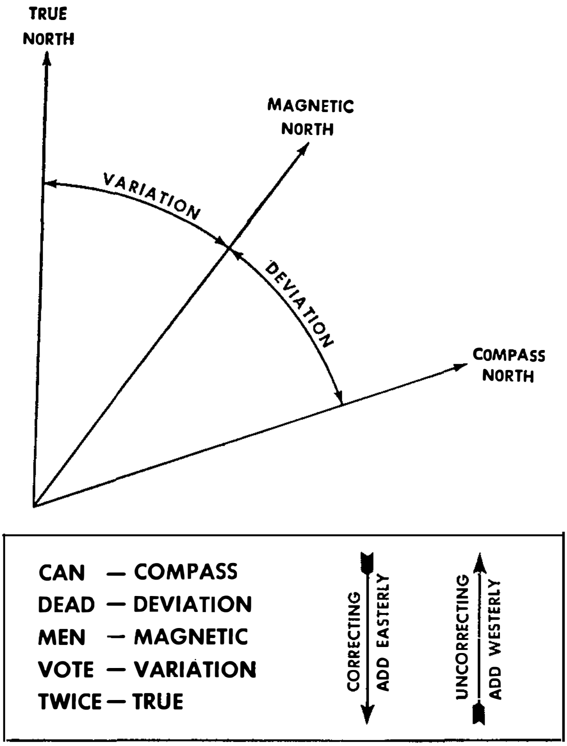


Figure 188.—Deviation.

Since these magnets do not completely counteract deviation, the compass will point either to the right or left of magnetic north. If the compass points to the right, the deviation is easterly. If to the left, the deviation is westerly.

The amount and direction of deviation varies with the ship's head. If, for instance, your ship is on a course of 130° the deviation may be 2° east, while a course of 265° may give you a deviation of 4° west. The navigator determines the compass deviations for his ship and records them in curve form on a deviation table. This table is kept near the compass.

CORRECTING AND UNCORRECTING

There are three ways in which a direction, bearing, course, or heading may be expressed:

1. As TRUE, when referring to the true (geographic) north pole.

2. As MAGNETIC, when referring to the magnetic north pole.

3. As COMPASS, when referring to the axis of the compass card.

Remember that true differs from magnetic by variation; magnetic differs from compass by deviation; and compass differs from true by compass error, which includes both variation and deviation.

You must thoroughly understand how to apply variation and deviation because you may be required to use them in converting from true to compass course, or vice versa. To convert magnetic course into true course, and true course into compass course, remember the relationship between the various factors shown in figure 188.

Here is an easy way to remember the formula—

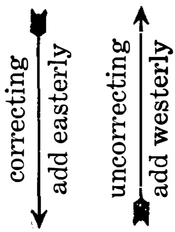
Can—Compass

Dead—Deviation

Men—Magnetic

Vote—Variation

Twice—True



To correct the compass course to true course, start with the reading of the compass and work down the table. Compass and deviation give you the magnetic sourse. The magnetic course, plus or minus the variation, will give you the true course. You have now corrected the compass course.

To change the true course to compass course you must uncorrect. To do this, start with the true course, and apply the variation to get the magnetic course. Then apply deviation to the magnetic course, and you will have the compass course.

Once you've mastered this system, all you have to remember is when to add a variation or deviation and when to subtract it. Here is the rule—

When correcting, add easterly.

If you are starting with the compass course and correcting to true course, you add easterly variation and deviation, and subtract westerly. The opposite is true when you are uncorrecting. That is, you subtract easterly and add westerly.

Try these two examples: Your compass course is 310° and you have determined from a table that your deviation is 3° west. According to the chart, the variation for your locality is 2° east. What is the true course that you are steering? (This is correcting, so add easterly and subtract westerly.)

310°		compass course
3°	W	deviation (subtract)
307°		magnetic course
2°	E	variation (add)
309°		true course

Now suppose the chart gave 155° as the true course to your destination. The variation is 5° east, and the deviation is 1° west. What course should you steer by your magnetic compass? (This is uncorrecting, so subtract easterly and add westerly.)

155°		true course
5°	E	variation (subtract)
150°		magnetic course
1°	W	deviation (add)
151°		compass course

COMPASS ERROR

The term compass error means the difference between the compass reading and the true reading. It is the net result, or algebraic sum, of the deviation and the variation. If, for instance, the deviation is 3° west and the variation 5° east, the compass error is 2° east. Or if the variation is 3° west and the deviation 6° west, the compass error is 9° west.

THE GYROCOMPASS

The gyrocompass is normally used on all except the smallest ships in the Navy. It is a fairly complex device that depends on electric current for its operation. There is no necessity for applying variation and deviation because the gyrocompass indicates true headings.

The master gyro is located in a well-protected part of the ship, and there are gyro repeaters in various locations on the ship, which follow the movements of the master gyro.

THE AZIMUTH CIRCLE

The azimuth of a celestial object, such as the sun, is its direction from the ship, reckoned from 000° at north to 360° clockwise. Azimuth is another name for bearing. An azimuth circle is shown in figure 189.

The circle consists of a nonmagnetic composition ring, formed to fit snugly over the compass bowl, about which it may be turned in any desired direction. Its inner lip is

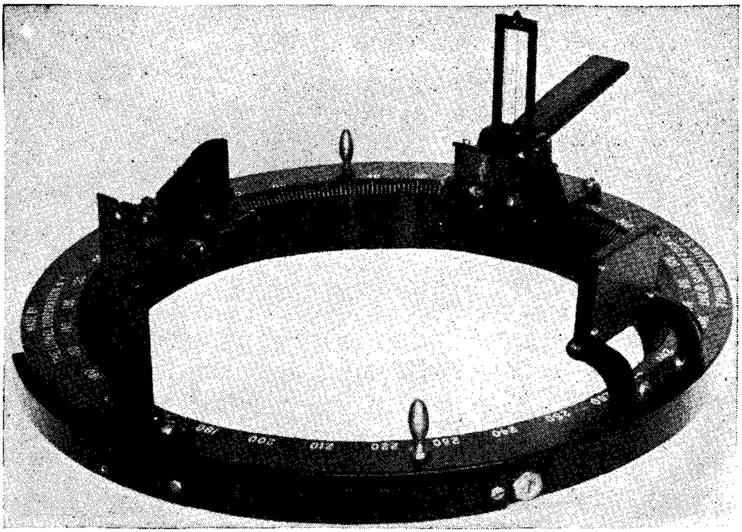


Figure 189.—Azimuth circle.

graduated like the compass card from 0° to 360°, but counterclockwise. A pair of sighting vanes is mounted on one diameter of this ring. They consist of a peep vane at one end of the diameter and a vertical wire mounted in a suitable frame at the other. To observe the bearing of a terrestrial object, look through the peep vane in the direction of the object, then by means of the finger lugs provided on the circle turn the circle until the object appears on the vertical wire of the opposite vane. The compass bearing of the observed object is then read by the position of the vertical wire on the compass card.

There is a dark glass reflector, movable about a horizontal axis, in the far sighting vane. This enables you to adjust it so that the reflected image of a celestial body may be brought to your eye and a compass bearing obtained.

A second set of appliances is located at right angles to the line of sight of the vanes. These appliances are designed especially for obtaining the compass bearing of the sun. To observe the compass bearing of the sun with this assembly, turn the azimuth circle until the sun's rays are reflected by the mirror to the prism. The bearing may then be read from the compass card.

A leveling bubble is provided and the azimuth circle should be exactly horizontal at the moment of observation.

Normally, bearings are taken with a device called a bearing circle, which is identical to the azimuth circle except for the attachments used for taking azimuths of the sun.

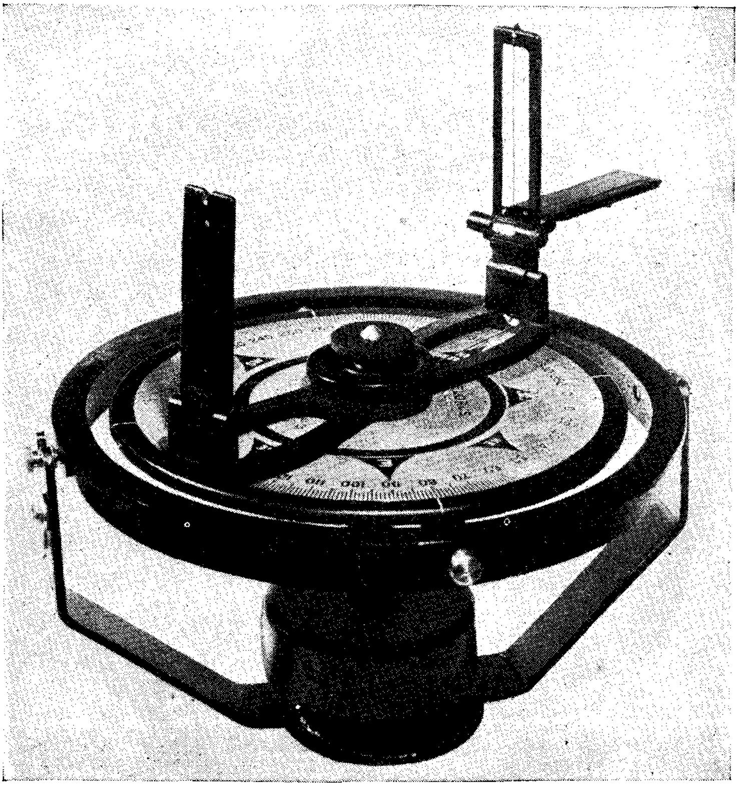


Figure 190.—Pelorus.

THE PELORUS

A pelorus or dumb compass (fig. 190) is used to take bearings if the ship has no gyrocompass. Usually located on a stand near the wings of the bridge, the pelorus consists of a pair of sighting vanes mounted over a movable compass card.

To obtain true bearings, set the pelorus to the ship's true course by turning the card until its true-course graduation coincides with the lubber's line. Secure the card and line up the sighting vanes on the object to be observed. Direct the steersman to sing out, "Mark! Mark! Mark!" when he is steady on his steering compass course. When he does this, take the bearing exactly and read the degree as indicated on the card by the sighting vanes.

Suppose the variation is 12° east, the deviation 2° west, and the compass course 175°. The magnetic course will be 175° minus 2° or 173°, and the true course will be 173° plus 12° or 185°. So the card in the pelorus must be set on 185°. The steersman will call, "Mark! Mark! Mark!" as he steadies on 175° with his steering compass, and at that time the true bearing is taken.

THE ALIDADE

The alidade (fig. 191) is the best device for taking accurate bearings. It employs a telescope with a hairline for sighting the object.

The telescope is mounted over a gyro-repeater and moves independently, enabling you to read the bearing accurately even though the ship is changing course.

LATITUDE AND LONGITUDE

The location of a ship is determined by finding the latitude and longitude of her position.

Longitude (fig. 192) is the distance in degrees of the point east or west of Greenwich, England. New York, for instance, is in longitude 74° west, which means that

Figure 191.—Taking a bearing with an alidade.

New York is 74° to the west of Greenwich, whose longitude is 0°. Sydney, Australia, is near longitude 151° east of Greenwich. Latitude is measured in degrees, north or south of the equator. For example, New York is in 40° north latitude or about 40° north of the equator, while Sydney, Australia, is about 34° south of the equator, or latitude 34° south.

CHARTS

You probably know already that several types of charts may be used in navigation. Large scale charts, for instance, usually cover a small area in great detail, with all features greatly enlarged, while small scale charts cover larger areas with fewer detailed features. Charts of larger scale are generally used in piloting.

Charts themselves are reproduced by any one of four methods. The chart used most often in navigation is based

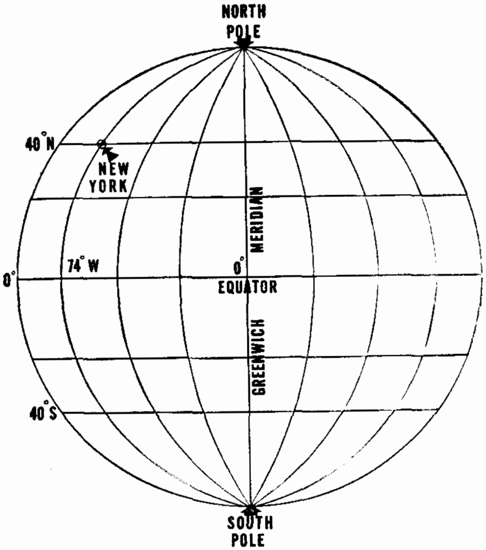


Figure 192.—Longitude is measured from Greenwich.

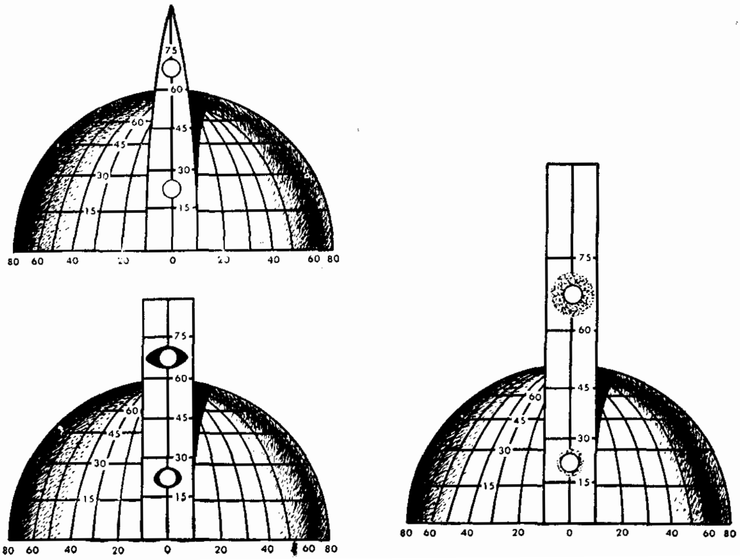


Figure 193.—The Mercator projection method.

upon what is called the Mercator projection. Figure 193 shows what happens to a portion of the globe when it is reproduced on a chart via the Mercator system.

First, the part that you are interested in (top left in fig. 193) is PEELED OFF and laid down flat. Then this portion is stretched out so that the meridians are parallel. Since the map has been stretched in one direction, it must be stretched in the other to prevent local distortions. So it is now stretched in the north-south direction, as at right in figure 194.

Inasmuch as the meridians were pulled farther apart near the poles, the parallels of latitude are also pulled further apart near the poles. This results in greater distortion in the northern and southern latitudes than near the equator. The distance scale that will work near the equator will not work near the poles. This is a disadvantage, but the property which makes the Mercator chart so useful for the purposes of navigation is that the d. r. (dead reckoning) track of a ship, as long as she steers the same true course, appears upon the chart as a straight line.

The latitude scales, which bound the charts on the east and west, are used for measuring distances. One minute (1′) of latitude is equal to one nautical mile, so 1° equals 60 miles. Since the minutes of latitude on a Mercator chart become farther apart as the latitude increases, the distance scale varies with the latitude. For this reason, always measure distance according to the latitude scale along the sides of the chart in the latitude in which the ship is sailing. The longitude scales bound the chart on the north and south. Never measure distances on the longitude scales.

Figure 194 is a section from the lower left-hand corner of a chart. The latitude scale is on the left (west). Measure the distance from *A* to *B* from the latitude scale opposite points *A* to *B*. Also, measure the distance from *C* to *D* from the scale opposite the latitude of points

C and *D*. Use dividers when you measure distances on a chart.

READING THE CHART

If a chart includes a great extent of latitude, the latitude scale on the side is used to measure distance. A large scale chart of a single harbor also has a latitude scale and, in addition, a scale graduated in yards and miles, which is more commonly used in measuring distances for a small area.

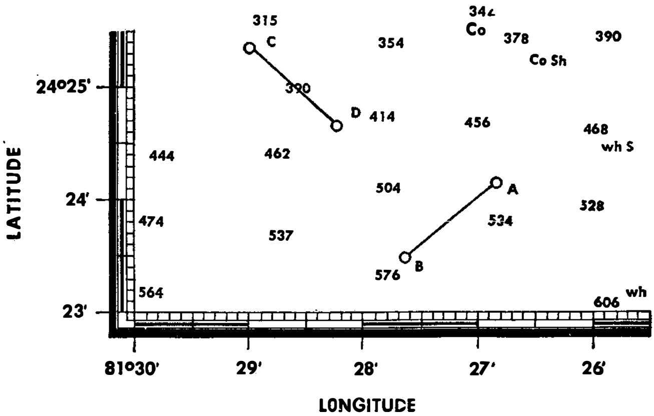


Figure 194.—Measure distances from the left-hand side of this chart.

There are many symbols on a chart that give the mariner important piloting information.

Bearing data is read from the compass rose printed on the chart. (See fig. 195.) The outer circle gives true bearings and can be used for plotting courses and bearings. The inner circle is rotated an amount equal to the variation given in the center. The annual rate at which the variation changes is also given.

Soundings are indicated at frequent intervals by small numbers distributed over the chart. These depths are given in feet on shallow-water charts, and in fathoms on deep-water charts. Lines are drawn along the points where the depth of the water is the same number of

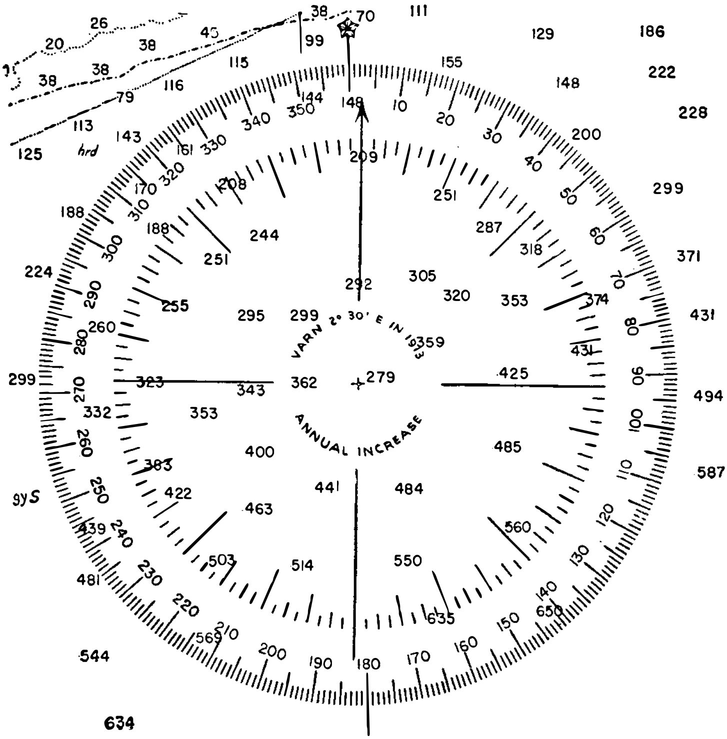


Figure 195.—Compass rose on a chart.

fathoms. These lines are called FATHOM CURVES. Three fathom curves are shown in figure 196.

Charts also tell at which state of the tide the depths are accurate. This is usually mean low tide. It is best to leave a margin for error in the interpretation of the soundings. Low tides may occur from causes—such as the wind—that cannot be predicted accurately.

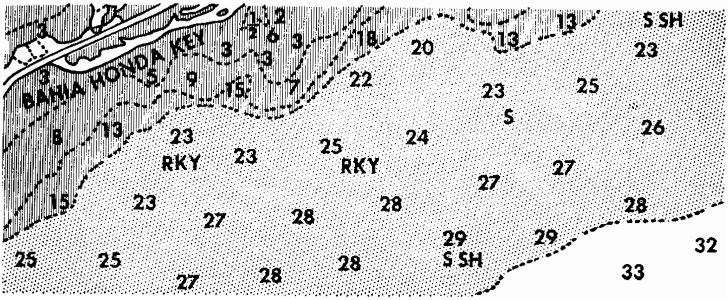


Figure 196.—Soundings in feet.

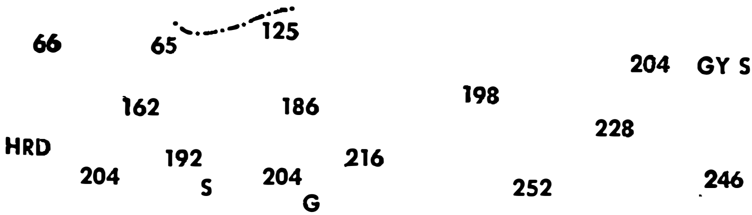


Figure 197.—Letters indicate type of bottom.

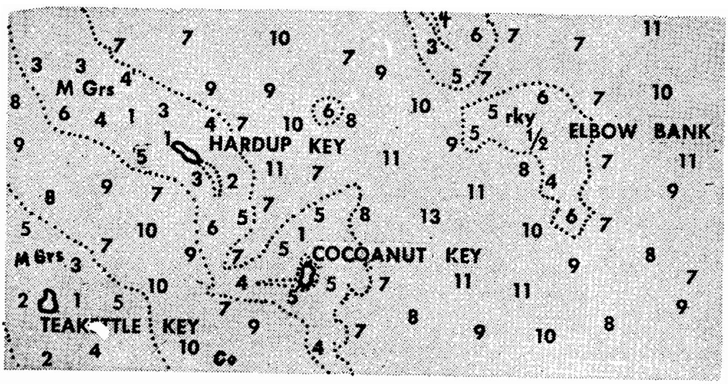


Figure 198.—Elbow bank submerged at high water.

At various points on the chart, letters indicate the nature of the bottom. Notice these letters in figure 197. Below is a table of their meanings.

Quality of the Bottom

Grd.	ground	Di.	diatom
S.	sand	fne.	fine
M.	mud	crs.	coarse
Oz.	ooze	sft.	soft
Ml.	marl	hrd.	hard
Cl.	clay	stf.	stiff
G.	gravel	sml.	small
P.	pebbles	lrg.	large
St.	stones	stk.	sticky
Sp.	specks	brk.	broken
Rk.	rock	rky.	rocky
Bld. (s)	boulder (s)	spk.	speckled
Ck.	chalk	gty.	gritty
Co.	coral	fly.	flinty
Co. Hd.	coral head	glac.	glacial
Vol. Ash.	volcanic ash	wh.	white
La.	lava	bk.	black
Pm.	pumice	bu.	blue
Cn.	cinders	gn.	green
Sh.	shells	yl.	yellow
Oys.	oysters	rd.	red
Spg.	sponge	br.	brown
Grs.	grass	gy.	gray
Gl.	globigerina	lt.	light
		dk.	dark

When there is no visibility, the fathometer may be used to compare the depth of the water with the recorded depths that appear on the chart.

You may also be able to locate your approximate position by bringing up a sample of the bottom and noting the depth on the hand lead. A hollow in the bottom of the lead may be filled with grease or tallow; when lowered, it collects sediment from the bottom. You can check the sediment against that indicated by your chart and thereby get an estimate of your position.

The high-water line is the shore line. Vertical lettering is used to mark all features that are dry at high water, and leaning letters (*italics*) are used for features that are submerged at high water. This lettering is illustrated in figure 198. LEANING LETTERS are also used to indicate floating aids to navigation.

The appearance of the coast line, special growths, permanent features ashore, and other aids to navigation are indicated on the chart. Many charts also contain information about the strength and direction of tidal and ocean currents.

AIDS TO NAVIGATION

Many charts, depending on the scale and the area covered, give the positions and characteristics of such navigational aids as lighthouses, lightships, radio beacons, fog signals, buoys, and beacons.

Extremely important to navigation are the special lights, lighthouses, and lightships placed at vantage points along the shore, on islands, and on shoals. At night, each light sends out a characteristic signal.

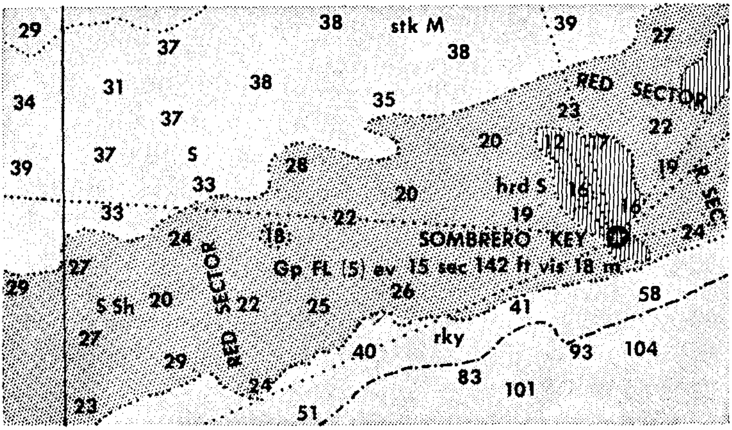


Figure 199.—Lighthouse details on chart.

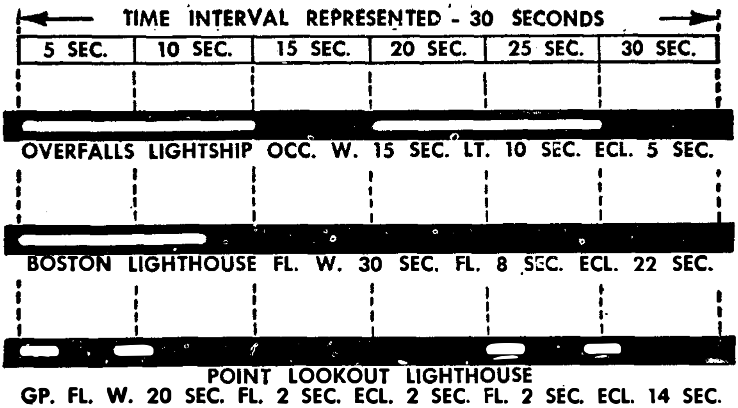


Figure 200.—Typical light characteristics.

The chart contains brief details of the lighthouse—the color of its light, its height, and the character of the signal it sends out. This information is printed in abbreviated form alongside the position of the lighthouse. *Light Lists,* a Hydrographic Office publication, must frequently be consulted for details on lighted aids.

The meaning of the abbreviations for light characteristics is given in the table illustrated in figure 201.

Lights are referred to as flashing when the light period is shorter than the dark period and as occulting when the light period is equal to or longer than the dark period. The period of a flashing or an occulting light is the time required for it to go through the full set of changes. A few examples of lights are illustrated in figure 200.

Besides the light characteristics, the height of the light above sea level and its visibility in miles are given on the chart. The visibility is for height of an observer's eye at 15 feet above sea level.

For a quick review, look at the legend in figure 199. It is Gp. Fl. R. (group flashing) (5) ev 15 sec 142 ft vis 18 mi. This means that the light flashes red in groups of 5

LIGHTS WHICH DO NOT CHANGE COLOR	CHARACTERISTIC PHASES	LIGHTS WHICH CHANGE COLOR
F. Gp. Fl. = Fixed and group flashing	A fixed light varied, at regular intervals, by a group of two or more flashes of relatively greater brilliancy. The group may, or may not, be preceded and followed by an eclipse.	Alt. F. Gp. Fl. = Alternating fixed and group flashing.
Qk. Fl. = Quick flashing	Shows not less than 60 flashes per minute.	
I. Qk. Fl. = Interrupted quick flashing	Shows quick flashes for about 4 seconds, followed by a dark period of about 4 seconds.	
S-L. Fl. = Short-long flashing	Shows a short flash of about 0.4 second and a long flash of 4 times that duration, such groups repeated about 8 times a minute.	

W = White	R. = Red	G. = Green	Lights without color indication are white.

Figure 201.—Abbreviations for light characteristics.

Restricted

flashes every 15 seconds, that it is 142 feet above sea level, and visible 18 miles from a height of 15 feet.

BUOYS

The United States buoyage system employs several different types of buoys. Each kind is designed to serve under different conditions. All buoys serve as daymarks. Those equipped with lights are available for navigation at night. Buoys equipped to give sound signals are located more easily in fog as well as at night. Eight general types of buoys are illustrated in figure 202.

CAN and NUN buoys are made of steel plates. The can buoy has a flat top while the top of the nun buoy comes to a peak. The nun buoy is painted red, carries even numbers and is placed on the right-hand side of the channel as you enter from the sea. You can remember it by the phrase "red right returning." The can buoy is painted black, bears odd numbers and is on the left-hand side as you are returning from sea.

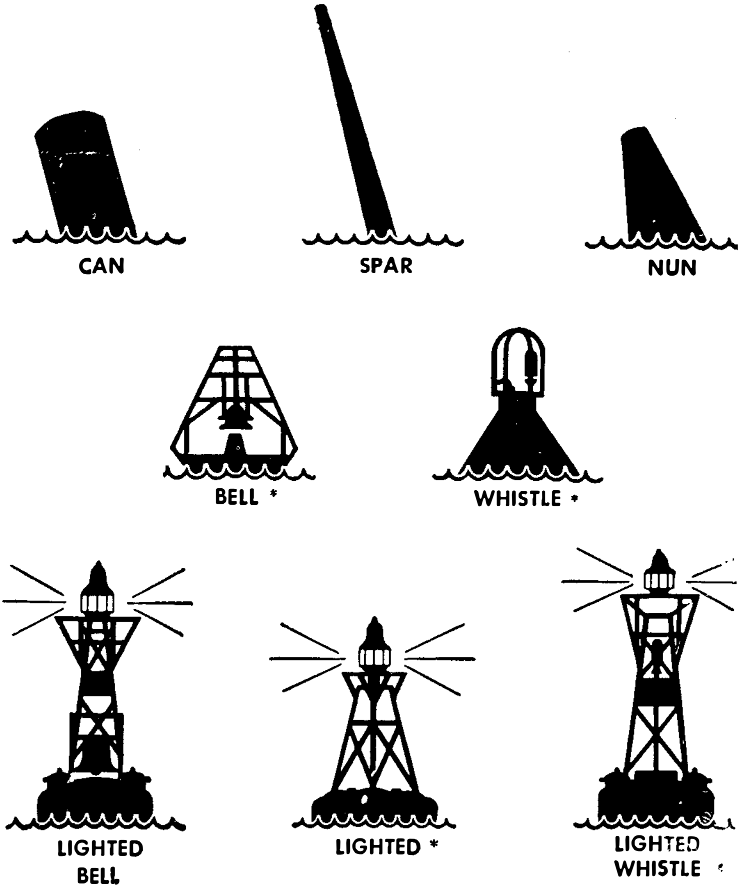
The SPAR buoy is a large log, trimmed, shaped, and appropriately marked. It may be on either side of the channel, colored either red or black and its numbers odd or even depending on which side of the channel it is placed. Buoys of the same spar shape are also constructed of steel plates. The spar buoy may replace either the nun or can buoy.

The BELL buoy is a steel float surmounted by short skeleton towers in which the bell is fixed. Most bell buoys are sounded by the motion of the buoy on the sea. In newer types, the bell is struck by compressed gas or an electrically operated hammer.

The GONG buoy is similar in construction to the bell buoy. It sounds a distinctive note because it uses a set of gongs, each of which has a different tone.

The WHISTLE buoy provides a sound signal that is useful at night and also during fog or periods of low visibility. As the whistle mechanism is operated by the motion of the buoy in the sea, this buoy is used principally in exposed locations.

The LIGHTED buoy is a metal float. A short skeleton tower is mounted on the float and the lens is placed on



SHAPE MAY VARY*

Figure 202.—United States Buoys.

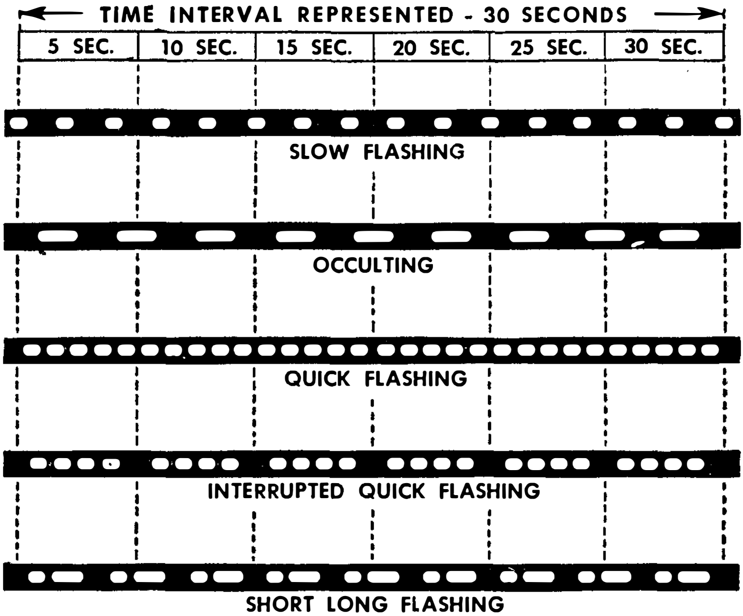


Figure 203.—Buoy light characteristics.

top of the tower. The light is operated by tanks of compressed acetylene gas, or by electric batteries placed in the body of the buoy below the water level.

The COMBINATION buoy combines a light and a sound signal. Other combinations are the lighted bell buoy, lighted gong buoy, and lighted whistle buoy.

The buoy light characteristics, similar to those of lighthouses, are illustrated in figure 203. On the red or NUN side of the channel, the lights are white or red. On the CAN or black side, they are white or green.

Although some foreign nations employ their own systems, the following orders are observed in coloring and numbering the buoys along the coasts, in bays, harbors, sounds, or channels of the United States.

In approaching the channel from seaward, red buoys with even numbers will be found on the starboard side of the channel, and must be passed on the starboard hand.

In approaching the channel from seaward, black buoys with odd numbers will be found on the port side of the channel and must be passed on the port hand.

Buoys painted red with black horizontal stripes will be found on obstructions, with channel ways on either side of them. If this buoy is a spar or can, with a black top stripe, it is better to pass the buoy on the port hand as you go in. If the buoy is a spar or a nun with the red top stripe, it's best to pass it on the starboard hand as you go in.

Buoys with white and black vertical stripes will be found in midchannel and must be passed closely to avoid danger.

Buoys do not always maintain exact positions; therefore, they should always be regarded as warnings and not as fixed navigational marks, especially during the winter months or when moored in exposed waters. A vessel's position should be plotted by bearings on fixed objects on shore. Lighted buoys cannot always be relied on, because the light may go out or the mechanical apparatus may fail. Remember that whistle and bell buoys are sounded by the action of the sea and, in calm weather, are less effective and may not even sound.

The color, stripe, and light characteristics of buoys are indicated by chart symbols. The letters *C, N,* and *S* for can, nun, and spar respectively, will be found on the chart beside the buoy, as well as the word WHISTLE, BELL, GONG, or TRUMPET, depending on the type of buoy.

BEACONS

The beacon is another navigational aid that is important in piloting. It is marked on the chart either by a small triangle, or by the letters *Bn.*

Beacons are usually found on beaches, reefs, shoals, and so forth. Their color, shape, and size depend on the locality. They are designed to give maximum visibility against the background of their location. If the beacons are near a channel, their color will conform to that of the buoys.

DEAD RECKONING

Dead reckoning is simply the name applied to the method by which you determine your position at any given time by estimating the distance and direction you've traveled from the last definitely known position. You can estimate the distance traveled by checking the course steered to get direction, and the pit log or engine revolutions to get the estimate of distance traversed.

Positions by dead reckoning differ from those determined by bearings of terrestrial objects or by observations of celestial bodies. They are less exact, because the correctness of dead reckoning depends upon the accuracy of the estimated run. The estimated run may be in error because of imperfect steering, improper allowance for compass error, the leeway caused by the wind, the effect of unknown currents, or inaccurate logging.

Notwithstanding its recognized defects as compared with the more exact methods, dead reckoning is an invaluable aid to the navigator. It affords a means of plotting the ship's position at any desired time between fixes. It also gives an approximate position at the moment of taking astronomical observations which is a great convenience in working up those observations. Finally, aside from electronic aids, it affords the only available means of determining the location of a vessel at sea during those periods when weather makes the observation of celestial bodies impossible.

PLOTTING

There is a definite system for plotting bearings and courses on a chart. Your ship's course line is drawn as in figure 204.

The letter *C* and the course in three figures are printed above the line. The letter *S* and the speed in knots are printed below the line. The estimation of your ship's position on this line is known as the dead reckoning position and it is marked by d. r. and the time. Figure 205 illustrates three of these positions.

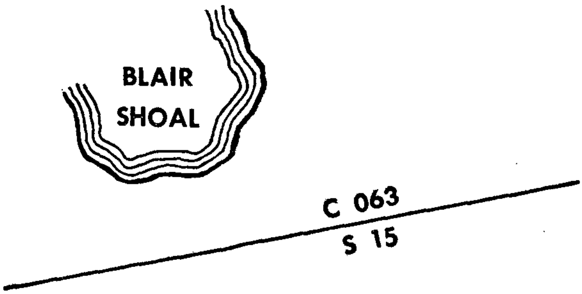


Figure 204.—Own ship's course line.

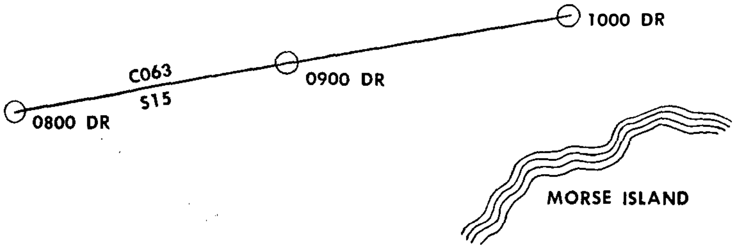


Figure 205.—Dead reckoning position.

Your ship's course line is started from some position that has been definitely established by sights on celestial bodies, or navigational aids. This position is known as a FIX. It is labeled with the time and the word fix (figure 206). All lines or points must be labeled as soon as they are drawn. The label for any line should lie along the line.

Your course line, when laid out from a fix, is really a succession of d. r. positions, a line generated by the constantly moving d. r. position, more properly called the d. r. track line. The d. r. track line, laid from a fix, continues as a graphic history of courses steered and engine speeds, until another fix is obtained. Winds, currents, slight steering errors, and other factors, as already explained, tend to retard or aid the ship's progress along this track. Thus, you continue the d. r. track from each new fix.

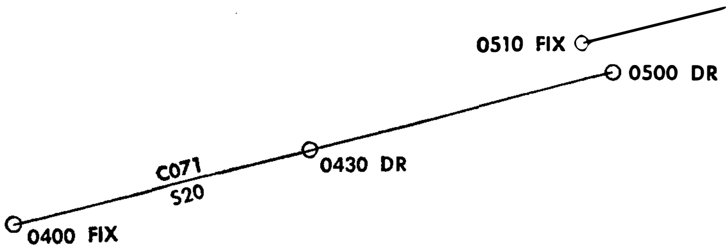


Figure 206.—The fix.

LINES OF POSITION

In piloting, as in celestial navigation, it is necessary to work with LINES OF POSITION. A single observation does not provide a position, but gives a line, straight or curved, on some point at which the ship is located. There are several methods for establishing lines of position. The simplest of these methods is by a RANGE.

For example (as in fig. 207), if two fixed known objects appear to be in line, as seen from the ship, the ship must, at that instant, be somewhere on the line of sight passing through the two objects. This line of sight can be indicated on a chart which shows the two objects. If, as shown in figure 207, you saw the light on Royall Bank at 1452, exactly in line with the light on Gillmore Bank, you would know that your ship is somewhere on the line passing through the two lights. Thus, the line between the two lights is your line of position determined from a range. Label this line with the time of sighting in four figures, as in figure 207.

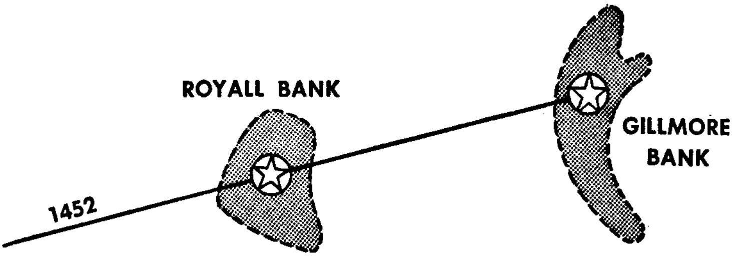


Figure 207.—Determining your line of position from a range.

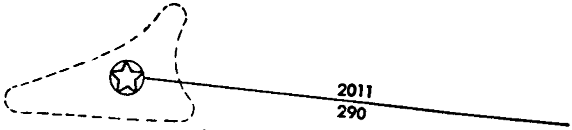


Figure 208.—Determining your line of position by bearing.

Another way of finding your line of position is by taking a bearing on a known object. Suppose that Sand Key light in figure 208 bears 200° from your ship. You know then that your ship bears 110° from Sand Key, so you can draw a line from Sand Key on bearing 110°. Your ship must be on this line. Label this line of position with the time in four figures above the line, and the bearing of the object from you in three figures below the line.

A third way to determine a line of position is by obtaining the distance to an object. Look at figure 209. If the radar indicates that American Shoal is at a range of 10,000 yards, your ship is somewhere on the circle with a radius of 5 miles drawn with American Shoal as its center. Mark the circle with the time above, and the range below.

THE FIX

Note that there is an infinite number of possible positions on any SINGLE line of position and, as you've seen, to fix your ship's position it is necessary to pilot two or more lines of position which intersect.

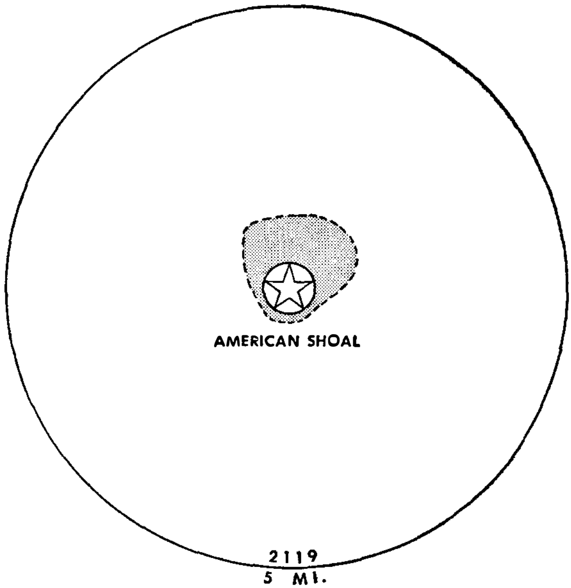


Figure 209.—Determining your line of position from distance to an object.

There are four methods of obtaining a fix: (1) From the bearings of two or more objects; (2) from the bearing and range of one object; (3) from the bearing of one object and the range of another, and (4) from the range of two objects.

CROSS BEARING OF TWO OBJECTS

At 1532, you observe that Sand Key light bears 290° and that East Martello Tower on Key West bears 017°. You plot in these lines of position. Your ship lies somewhere on both lines and, of course, your actual position is at the intersection of these two lines of position. Label this intersection the 1532 fix. You will draw the lines as in figure 210, with only a small part of each line of position drawn and labeled. These lines must be drawn lightly with a sharp hard pencil.

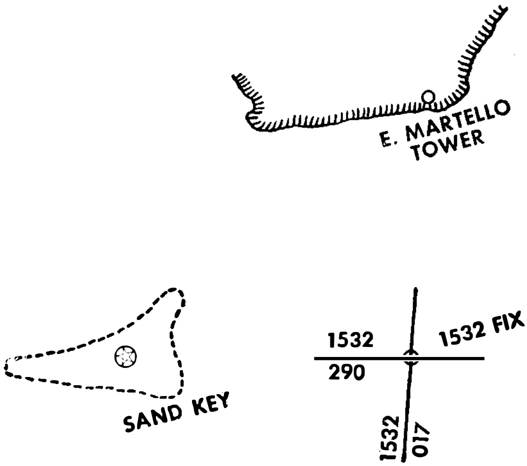


Figure 210.—Cross bearing of two objects.

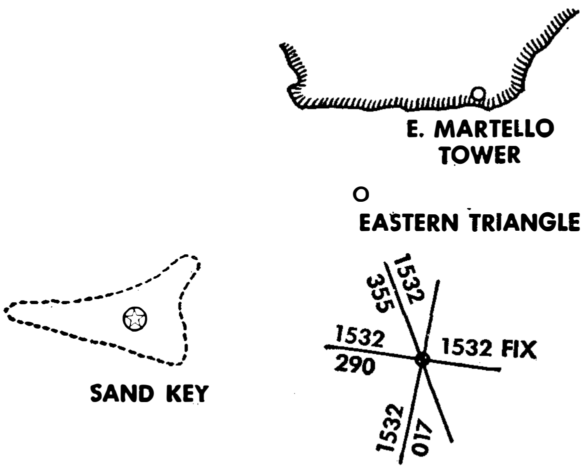


Figure 211.—Cross bearings of three objects.

BEARINGS OF THREE OBJECTS

You can obtain a more accurate fix by obtaining bearings on three objects, as illustrated in figure 211. At 1532 you obtain bearings from Sand Key, East Martello Tower, and Eastern Triangle. The third line of position serves as a check on the other two. If all three lines intersect at the same point, the fix is bound to be very reliable.

BEARING AND RANGE OF ONE OBJECT

You can obtain a fix by getting the bearing and range of one object as illustrated in figure 212. At 1532, you observe that Sand Key light bears 290° and that the

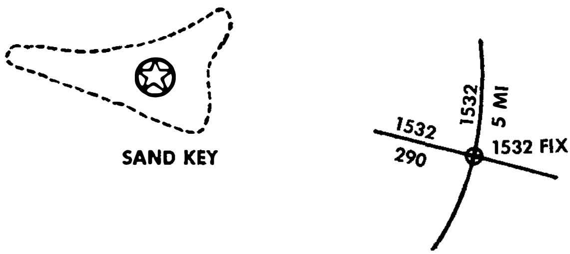


Figure 212.—Bearing and range of the same object.

range from your ship to Sand Key as supplied by radar is 10,000 yards. You can plot in these lines of position and intersect them to obtain your 1532 fix.

ONE BEARING, ONE RANGE

Another way of establishing your position is by getting a bearing of one object and the range of another. Look at figure 213. At 1547, the two lights on Key West are in range. At the same time Sand Key bears 261°. Plot and label these two lines and you will have your fix.

A vessel entering the harbor steams so as to keep range lights *A* and *B* (fig. 214) approximately in line. At 2153, with *A* and *B* exactly in line, light *C* and the airport beacon *D* are observed to be in line. Plot in these two ranges and label the 2153 fix.

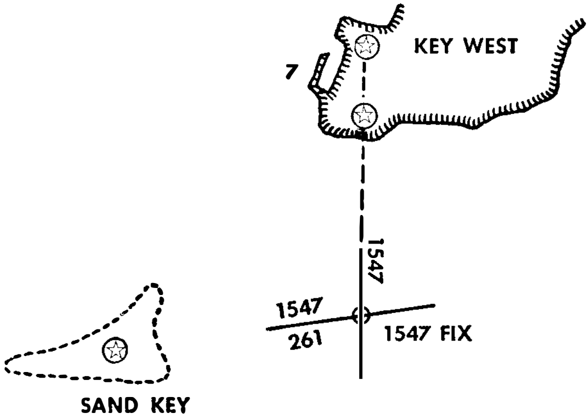


Figure 213.—One range and a bearing.

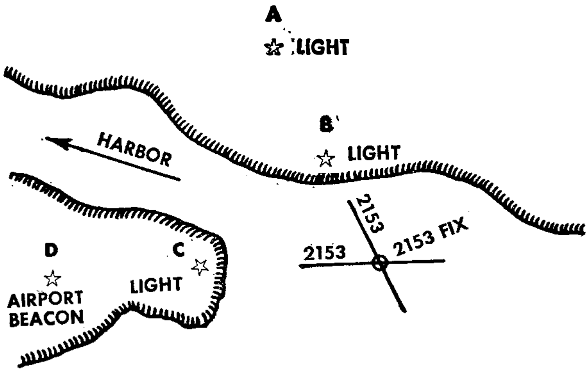


Figure 214.—Two ranges.

THE RUNNING FIX

It is not always possible to obtain two simultaneous lines of position. At such times, it may be possible to get a running fix, using two lines of position which were obtained by observations at two different times. In order to plot the running fix, you must make allowance for the time elapsed between the first observation and the second. This is done by advancing the earlier line of position.

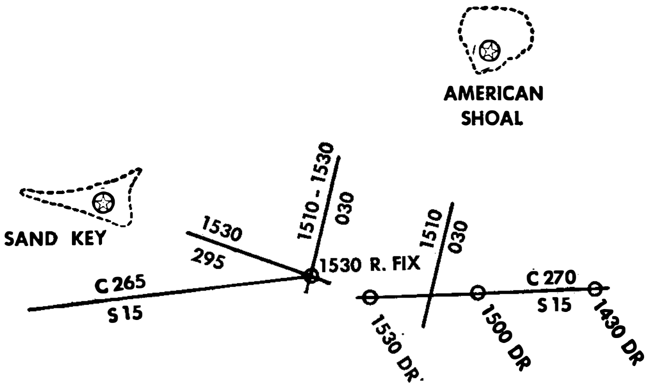


Figure 215.—The running fix.

You assume that you move a definite distance in a definite direction for a limited period of time between the two observations. You move the earlier line of position, parallel to itself, to this advanced position. The new advanced line now represents the possible position of the ship at the time of the second observation.

Look at figure 215. At 1510, you get a bearing of 030° on American Shoal. Then a rain squall sets in and you cannot get another bearing. Twenty minutes later, at 1530, you see Sand Key bearing 295°. During the 20 minutes between the two observations you were steering 270° and making a speed of 15 knots.

In order to get a running fix, draw your d. r. track line and your 1510 bearing on American Shoal. From 1510 to 1530 you went 5 miles at a speed of 15 knots, so advance your 1510 bearing, parallel to itself, 5 miles along the track line to the new position marked 1510-1530. Now plot your 1530 bearing of Sand Key and you have your 1530 running fix.

This is not an accurate fix inasmuch as you advanced your 1510 sight on the assumption that you made good both course 270° and speed 15, or five miles in the direction of 270°. The longer the time that a line is advanced, the greater the chance for error.

LORAN

Electronic Navigation

Loran is a system of position finding on the sea or in the air, by reception of radio signals from transmitting stations of known position. Ships may use loran signals only if they have loran receivers and appropriate loran charts or tables issued by the Hydrographic Office. The name is a term derived by combining the initial letters of LOng RAnge Navigation.

This system furnishes reliable positions to navigators at greater distances from the transmitting stations than is possible by ordinary methods of radio navigation. Loran operates on a frequency of about 2,000 kc. This is the region of the radio spectrum just above the commercial broadcast band. The longer waves of loran travel over the surface of the earth, and skyward, encountering the electrically ionized region of the upper atmosphere, which is called the ionosphere, and may be reflected back hundreds of miles from the sending antenna. This is what makes the long range of loran possible. With present techniques, the limit of distance is about 1,400 nautical miles by night and about half of this by day.

Loran operates on the following principles:

1. Radio signals consisting of short pulses are broadcast from a pair of special shore-based transmitting stations.
2. These signals are received aboard ship on a specially designed radio receiver.
3. The difference in time of arrival of the signals from the two stations is measured on a special indicator.

4. This measured time difference is utilized to determine directly from special tables or charts a line of position on the earth's surface.

5. Two or more lines of position, determined from two or more pairs of transmitting stations, are crossed to obtain a loran fix.

Thus, loran is entirely different from radio direction finding, for it measures time of arrival of radio waves, rather than direction of arrival. Loran, therefore may use simple straight wire antennas, rather than loops or complicated directional antenna arrangements.

Principles of Operation

A loran transmitter broadcasts short power bursts or pulses of radio energy into space in all directions. Each pulse lasts about 40 microseconds (40 millionths of a second). The pulses recur at regular intervals and the transmitter is inactive for a relatively long period (40,000 microseconds for example) between recurring pulses. The short pulses of radio energy provide precise index marks for use in time measurements.

The radio pulses travel out from the transmitter at a rapid but constant and known velocity of 162,000 nautical miles per second, or 983 feet per microsecond. Distance can thus be measured in radio wave travel time as readily as in miles or feet, provided suitable measuring methods are used. For this purpose two transmitting stations are synchronized to give loran signals.

In the actual loran system, a method of staggered pulsing has been adopted. First one station, known as the MASTER or *A* type station, transmits a pulse. After reception of this pulse, the other station known as the SLAVE or *B* type station waits a definite fixed time equal to one-half the pulse recurrence interval plus an additional short interval known as the coding delay, then transmits its pulse.

At all points the time interval from a master station pulse to the next master station pulse is greater than the interval from a slave station pulse to the next master station pulse. This difference in intervals provides a positive method of identifying signals, even though the two signals look alike. Since the interval between pulses as transmitted is constant, the basic principles of the simultaneously pulsed system have not been altered.

In the measuring process, the time difference is always measured from the master station pulse to the slave station pulse and, as will be described, the time delay of one-half of the pulse recurrence interval is automatically removed. The net result is to provide a family of loran lines-of-position for each pair of stations that have a shape identical to those secured with simultaneous pulsing; but now the minimum reading occurs along the base-line extension beyond the slave station and the readings increase continuously to a maximum along the base-line extension beyond the master station. There is now a single line for each time difference.

The lines of constant time difference for each pair of stations are all precomputed taking into account curvature and eccentricity of the earth and other factors.

Loran shore transmitting stations are usually arranged so that the two stations of a pair are separated by 200 to 400 nautical miles, but under unfavorable geographical situations the separation may be as little as 100 or as much as 600 miles.

Loran stations are arranged so that signals from two or more pairs of stations may be received in certain areas, and thus a loran fix is obtained by crossing two or more lines of position as shown at point X in figure 216. In regions where it is geographically impossible to locate more than one of a pair of loran stations, a single pair may be installed to provide single lines of position for homing purposes.

To economize on station installations, one station is often made common to two pairs. The station common to both pairs is double-pulsed. Double-pulsed stations, however, send out two entirely distinct sets of pulses, one set paired with the pulses from each adjacent station.

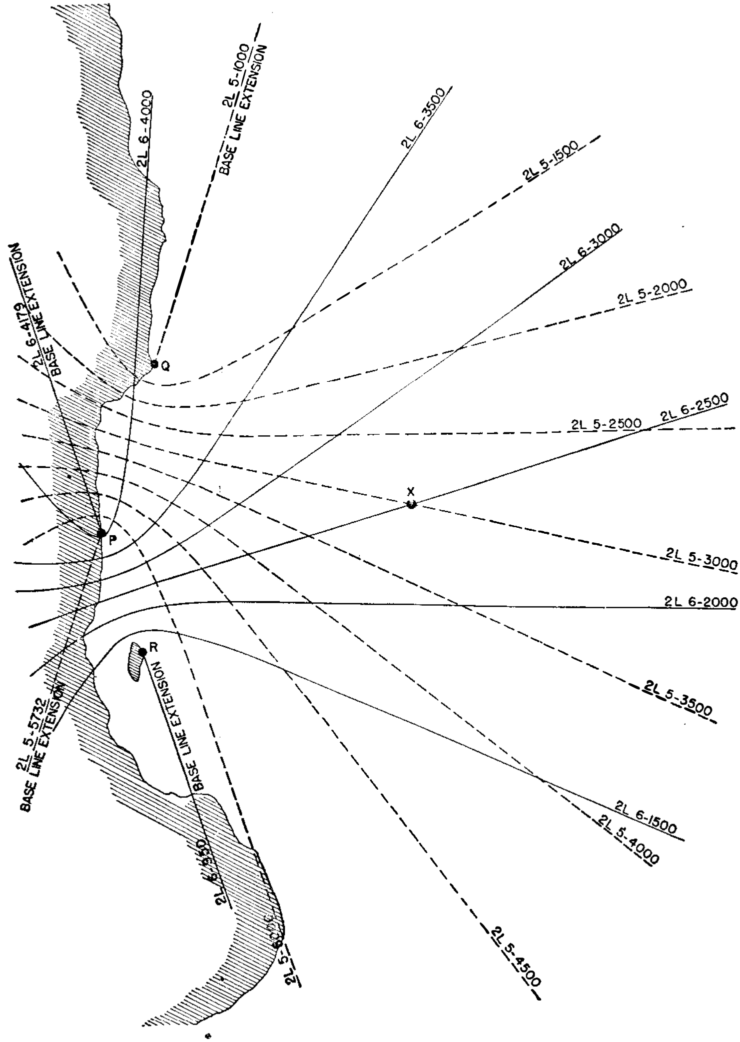


Figure 216.—Loran fix.

Therefore, from an operating viewpoint, a double-pulsed station can be considered as two separate stations at the same location.

THE LORAN RECEIVER

Loran signals are received aboard ship on a loran receiver. It is basically similar to an ordinary radio receiver, but especially adapted to loran. The output of the receiver does not go to a loud speaker or earphones, but to a loran indicator. The indicator is essentially an electronic watch, whose time record is made visible by the use of a specially designed cathode-ray oscilloscope. The indicator measures, in microseconds, the difference in time of arrival of the pulse signals from the two stations of a pair. Different groups of loran stations operate on different radio frequencies or wave lengths, just as do ordinary radio stations. The loran receiver switches between severed pretuned radio frequency channels much on the same principle as a push-button receiver.

To economize on radio frequency channels a number of pairs of loran stations are operated on the same radio frequency channel, but each pair operated at a different pulse-recurrence rate. Signals from all loran stations on the same channel appear on the scope screen if the ship is within range of the stations, but these signals drift across the screen at varying speeds. The operator can select a pair of stations by means of switches which make the sweep-recurrence rate of the desired pair. These signals will then be stationary, while signals from other pairs drifting across the screen can be ignored.

GROUND WAVES AND SKY WAVES

The range of loran stations, the type of signal received, and the accuracy of the resulting time difference measurement are affected by the path over which the radio waves travel. A portion of the radio energy travels out from the transmitter parallel to the surface of the earth.

This is known as the ground wave. Another portion of the radio energy travels upward and outward, encounters electrified layers of the atmosphere (known as the ionosphere) and if conditions are favorable is reflected back to the receiver. Reflections from the ionosphere are known as sky waves.

The loran indicator will give a reading no matter what ground wave or sky wave pulses are matched, but to get the correct reading the proper pulses must be selected.

The sky-wave correction (from loran charts and tables) compensates for the fact that the one-hop *E* sky wave path is longer than the ground wave path. Loran lines of position in tables and charts are computed on the assumption that the signals travel via the ground path. The sky-wave correction reduces a sky wave time-difference reading to an equivalent ground wave time-difference reading so that the lines of position in tables and charts can be used.

PLOTTING THE SHIP'S POSITION

Precomputed lines of constant time-difference for each pair of stations, taking into account curvature and eccentricity of the earth and other factors, are made available to the navigator by the United States Hydrographic Office in the form of loran charts and tables. The navigator has merely to follow a methodical measuring procedure aboard ship, then go directly to the charts or tables and interpolate between plotted or tabulated lines of position to determine the exact line corresponding to the measured time-difference.

LINES OF POSITION

A single observation or indicator reading denotes a line of position on the earth and on the navigator's chart. Lines of position corresponding to readings that are multiples of twenty (or some other convenient number) appear on loran charts. In general, the navigator's reading will not coincide with one of these. He must draw in a line, properly interpolated between the adjacent chart line and parallel to them. An observation of pulses from another pair of stations gives the navigator a second line of position intersecting the first line, and it is similarly drawn and labeled with the reading and watch time. The navigator must consider the ship's movement and advance or retard the fix in conformity with accepted navigational practice.

When greater accuracy than can be obtained from small-scale charts is necessary, loran tables are used. From them are extracted the latitude and longitude of two (or three for greater accuracy) points at which the reading would be obtained. A line is drawn on the chart through these points. This is a line of position and corresponds to the lines of a loran chart.

Loran stations are arranged so that the crossing angles of the lines of position from various pairs of stations are as consistent as possible with geographical considerations. Over large parts of the service areas of loran stations, crossing angles of 30° or better are obtained. Near the extreme limits of sky-wave coverage, when all the stations are situated along one coast or in a similar arrangement, crossing angles may be quite small. In this situation positions are obtained with relatively good accuracy in the direction perpendicular to the lines of position but with relatively poor accuracy along the lines of position. Where crossing angles are small, the practice of averaging a number of readings will result in considerably improved fixes.

ACCURACY

The accuracy of a loran fix is determined by the accuracy of the individual lines-of-position used to get the fix and by their angles of intersection. The accuracy of an individual line-of-position in turn depends upon the following factors:

1. Synchronization of the transmitting stations.
2. Skill in matching and identifying signals.
3. Uncertainty of sky-wave correction (when sky waves are used).

RANGE

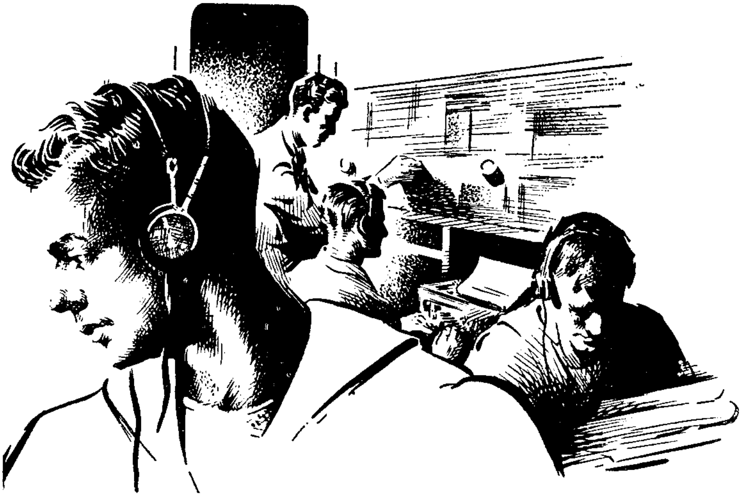
The range of loran stations depends on the type of signal received. The ground wave has a range over water of some 700 miles during daylight and somewhat less at night due to the increased atmospheric noise level. The ground wave travels about 200 miles over land.

The *E*–layer sky-wave signal can be used from within 250 miles of the stations out to about 1,400 miles. The sky-wave signals are usually received only at night; during the daytime the signals are absorbed in the ionosphere instead of being reflected back to earth.

QUIZ

1. What are the two parts into which the subject of navigation may be divided?
2. What is the fundamental difference between a magnetic compass and a gyrocompass?
3. What is meant by VARIATION?
4. What is the cause of DEVIATION?
5. What is the process of changing true course to compass course called?
6. What is the correct name for a "dumb compass"?
7. What scale is used for determining distances on a chart?
8. One minute (1′) of latitude is equal to what distance on a chart?
9. What is a compass rose on a chart?
10. What is meant by a fathom curve, as shown on a chart?
11. On a chart, what do the letters *C*, *N* and *S* indicate, as applied to types of buoys?
12. When plotting, where do you place the label for a particular line?
13. What is the fundamental difference between loran and radio direction finding in determining positions at sea?

14. How is it possible for several loran stations to transmit on the same frequency without causing interference?
15. Why must loran sky waves be corrected before they are usable?
16. How are loran stations identified?



CHAPTER 15

SUPERVISION AND WATCHES

MOVING TRAFFIC

In any communication office, keeping the traffic clear and maintaining discipline in the radio room and on radio circuits is largely the responsibility of the supervisor of the watch. He must know all communication instructions and have at hand all pertinent publications for ready reference. At sea, he should know the cruising disposition of the fleet in order to properly handle traffic. He should be familiar with his own radio equipment and with that of the various types of vessels in company. With this information he will be able to recognize and allow for personnel and materiel limitations of other units.

The primary functions of any communication office is to clear outgoing traffic with a minimum of delay, receive messages correctly, and disseminate incoming information rapidly to the officer(s) concerned. Even though instructions indicate a certain procedure is to be followed in intraship delivery of messages, if the importance of the message warrants, the system should be bypassed and delivery made to the addressee immediately. Information received too late is of little value.

If your ship has separate communication and CWO offices, the messages after being received, checked, and logged by the supervisor are delivered to the CWO who is responsible for routing them to the officer(s) concerned. Usually on these vessels traffic handed to the radio room for transmission is routed by the CWO.

On smaller ships where there are no CWo's, the supervisor is responsible to the communication officer for routing, filing, and delivery to the addressee. He should see that acknowledgments and replies are promptly made and, in general, should assume the duties of a CWO.

Before taking over a watch, the supervisor obtains all information possible concerning circuit conditions, special orders, cruising disposition, traffic on hand, acknowledgments and replies pending, officers aboard, guardships, ready-duty vessels, medical guard vessels, control circuits in use, frequencies guarded and transmitters in use. He should see that all necessary publications are in the radio room. Codes and ciphers in custody of the supervisor must be sighted before the on-coming supervisor signs for the watch.

When in port, the names of all Radiomen aboard should be obtained in order to provide for extra watches in emergencies. This list will include radiomen who rate liberty but have remained aboard.

Before turning the watch over to his relief, the supervisor should assure himself that the men under him have been relieved and that all traffic in the daily file has been checked for delivery. He should pass to his relief all relevant information and assure himself that his relief thoroughly understands the situation.

It has been said the "proper procedure is the best method of challenge and reply." This means, when proper procedure is used by operators at all times on the circuits, the individual operator has a better chance to confirm the fact that he is in communication with Navy forces instead of enemy vessels using Navy calls and procedures for deception. In order to reduce to a minimum the time required for delivery of traffic and to eliminate errors and unnecessary transmissions, established procedures must be strictly enforced. Every communication office has a copy of *Joint Communication Instructions* which contains examples of every type of message. When following the instructions in *JCI* there is no excuse for bungled routing, incorrect framing of messages, and service messages with garbled meanings.

From time to time you will receive instructions which are advance changes to existing doctrine, or instructions for temporary procedures to be used only as the need arises. You will find that such instructions may be at variance with standard frequency plans, and also that the calls of unit commanders and vessels may have been altered. Prior to fleet exercises, the supervisor should study these instructions so as to have the latest information for use during maneuvers. Special calls, authenticators, and any other information required should be posted at all operating positions to enable the operators to properly handle their circuits.

On most vessels that require supervisors for radio watches, the transmitting equipment is remote from the receiving room. The supervisor must be sure that transmitters are tuned and available as necessary. He must be familiar with all equipment on board and be able to tune, operate, and patch the equipment with minimum delay.

Regulations require that a log be kept of everything sent or received on a circuit. It is the supervisor's duty to see that these regulations are strictly complied with. A vague log indicates an inefficient supervisor.

The importance of a properly kept log cannot be overestimated for it serves three important purposes: (1) It is an official permanent record of transmissions on a particular circuit; (2) messages concerning your command, although not so addressed, may be written up from an accurate log and delivered to interested officers; and (3) an accurate log gives your commanding officer a running picture of all that is happening in other units of the force. A log of intercepted traffic enables him to secure information regarding the location or intentions of unfriendly forces. Circuit logs must be checked periodically and messages of interest to any officer aboard written up and delivered.

TELETYPEWRITER SUPERVISION

On nearly all stations—shore and shipboard—the Radioman will come in contact with teletypewriter communications. In many cases the watch he supervises will include both radio and teletypewriter equipment and personnel. The Radioman's supervisory duties will naturally vary according to the station to which he is assigned. He may be supervisor of the watch for a shipboard teletypewriter station, a shore station message center, or an NTX relay center. At the present time, ships are not a part of the Naval Teletypewriter System. Radioteletypewriter messages are sent to and received from the various primary and major communication centers. They are then placed on the NTX tape relay network for further transmission as may be required.

A supervisor can expect his equipment to vary slightly according to his billet. For instance, aboard ship and at a shore message center, model 15 printers and model 19 sets handle the bulk of traffic. At NTX relay centers the supervisor finds himself in contact with semiautomatic equipments—bank transmitters in tandem, receive consoles, tape factory, etc.—capable of handling heavy loads without loss of circuit time.

As in radiotelegraphy, the teletypewriter supervisor is the operator's trouble-shooter.

By working closely with his own personnel and the supervisors of other stations he is in a position to provide the Navy with a steady flow of high speed communications. The need for cooperation can be understood when you realize that a primary NTX station, such as Washington, handles a traffic load of 18 to 20 thousand messages in a single day.

When a transmitting or receiving position is functioning properly, the supervisor does not handle the tapes—except FLASH and EMERGENCY messages. Normally he checks his personnel to make sure that all positions are manned, and keeps tabs on the number sheets, noting whether any discrepancies exist. AS FLASH and EMERGENCY precedence messages are routed over NTX, they are handled from station to station by supervisors, with receipts exchanged all along the line. *Joint Communication Instructions* specifies that FLASH messages SHALL be handled by supervisory personnel, and EMERGENCY messages SHOULD be so handled. As a rule of thumb, you'll find that such high precedence traffic will always be processed by the supervisor. But, check your station regulations on this point.

When a FLASH or EMERGENCY tape has been transmitted, the supervisor records the channel number and station serial number on the sent number sheet. He waits until the distant station receipts for the transmission, then enters his sign on the number sheet. When a receipt is not received promptly, channel numbers and/or station serial numbers are used as a means of tracing. All traffic movement is stopped on channels over which FLASH transmissions are being made until station-to-station receipts have been exchanged and completed.

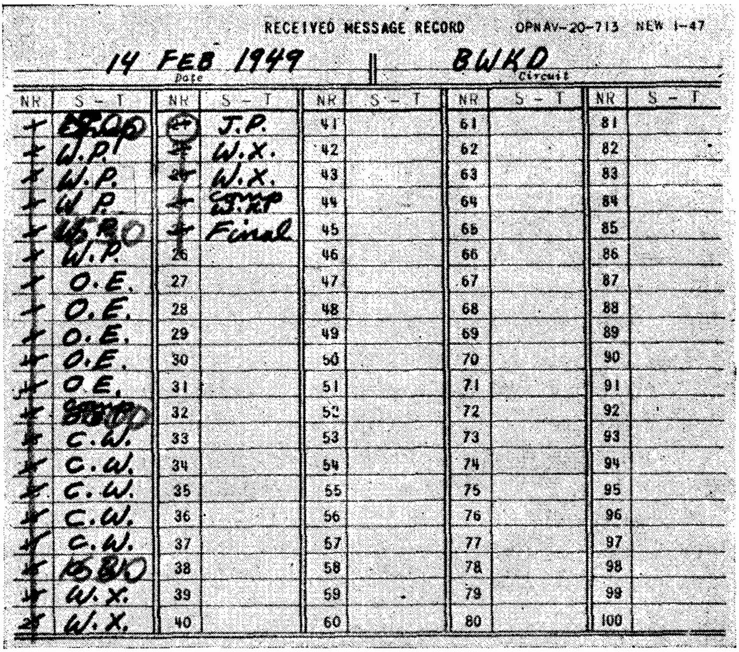
Other tapes handled by the supervisor include those containing the prosign BUST THIS. When a busted message comes from a station using channel numbering, the supervisor crosses the number off the received number sheet, and enters the letter *B* beside the crossed-off number. When a busted message comes from a tributary station and the number is "filled in" (used again for the next message) he does not cross the number of the busted message off the received number sheet. In both cases, the busted message tapes are filed by the supervisor.

The supervisor also investigates unusual or too frequent rerun and repunch requests so that action may be taken to eliminate possible equipment difficulties.

The inspection of received number sheets is an important function. Although operators are responsible for the maintenance of these sheets, the supervisor makes an inspection of each position every 30 minutes to make sure the record is being correctly kept. After inspecting a number sheet and finding it in order, the supervisor draws a vertical line through the number inspected. This line is drawn in the Channel Number column and extends down to the first open number. He then places his sign in the S–T column. If no numbers have been crossed off since the last number sheet inspection, the supervisor transmits a number comparison notice. He continues to transmit this notice at 10-minute intervals until a reply is received. No channel is allowed to remain idle for more than 1 hour without having received traffic, or a number "comp." Of course, no number comparisons are transmitted when a channel is closed for a designated period of time. When a circuit is down, the number sheet should be placed upside down in the holder.

The supervisor sees that completed number sheets are removed and replaced by new sheets. He gives all completed sheets a final check for irregularities, enters his sign, and files the sheets.

It is important that the supervisor of a relay center concentrate on incoming messages first. He should see that they are separated and distributed to sending grids in the proper order of precedence. When traffic loads are heavy, the rotation of personnel is an item to be kept in mind. Qualified operators should be rotated



RECEIVED MESSAGE RECORD OPNAV-20-713 NEW 1-47

14 FEB 1949 (Date) BWKD (Circuit)

NR	S - T	NR	S - T	NR	S - T	NR	S - T	NR	S - T
	[illegible]		J.P.	41		61		81	
	W.P.		W.X.	42		62		82	
	W.P.		W.X.	43		63		83	
	W.P.		[illegible]	44		64		84	
	[illegible]		Final	45		65		85	
	W.P.	26		46		66		86	
	O.E.	27		47		67		87	
	O.E.	28		48		68		88	
	O.E.	29		49		69		89	
	O.E.	30		50		70		90	
	O.E.	31		51		71		91	
	[illegible]	32		52		72		92	
	C.W.	33		53		73		93	
	C.W.	34		54		74		94	
	C.W.	35		55		75		95	
	C.W.	36		56		76		96	
	C.W.	37		57		77		97	
	[illegible]	38		58		78		98	
	W.X.	39		59		79		99	
	W.X.	40		60		80		100	

Figure 217.—Correct way to mark a received number sheet, supervisor's entries in red pencil.

between sending and receiving position at least every 2 hours. During peak-load periods, when the number of operators assigned to receiving positions outnumbers the operators assigned to sending positions, the rotation should be made every hour.

At 24ØØ GCT the supervisor directs the closing-out of channel numbers and prepares the traffic load study report.

ROUTING TRAFFIC

The supervisor, regardless of whether the office has a CWO, is responsible for the ACCURACY of the routing of all traffic handled by him. Before an outgoing message is placed on the circuit, or before a received message is written up for delivery the address, routing, and group count should be checked for accuracy. In cases where the message is misaddressed, the text is obviously incorrect, the text or procedure is in violation of instructions, or the message apparently carries the wrong precedence, the attention of the CWO or the radio officer should be called to the error. A decision must be made regarding the return of the message to the originator for confirmation or verification.

Definite instructions are usually posted by the radio officer to indicate persons authorized to release outgoing messages. It is the responsibility of the supervisor to see that such a release appears on all outgoing messages handed him for transmission. In case there is any doubt concerning the release of a message, the supervisor must consult the CWO or radio officer before release is made.

As assistant to the radio officer, the supervisor should develop the faculty of thinking as the radio officer does. This places him in a position to handle situations which arise in the same manner that the officer would handle them. Further, the supervisor must inform himself of all changes in the existing organization and of any other matters varying from the normal. The commanding officer or flag officer looks to the communication or radio officer for information, and it is the duty of the supervisor of the watch to keep himself informed so that he may present a complete picture of communication activities when called upon to do so.

The relationship between the supervisor and the communication or radio officer must be based on confidence, for efficient communications require mutual trust between the Radiomen and their radio officer. A supervisor can do his part to attain this objective by being alert and conducting his watch in such a manner that his radio officer respects his ability. When failures in the system occur—as they sometimes do in all offices—the radio officer will recognize the fact that although the mistake was avoidable his supervisor is nevertheless efficient, and the fault does not require disciplinary action, but provision to prevent a recurrence.

From his experience in traffic handling, the supervisor should be able to establish times of peak traffic loads. This knowledge enables the supervisor to equalize the load by segregation of messages according to precedence, and transmission of messages within precedence groups according to the time of origin.

The service and transmitting data of any outgoing message brought to the supervisor's desk should be carefully checked. Incoming messages must have address and group count checked, and the supervisor should determine whether a relay is involved. When handling heavy loads of traffic, relay responsibilities are easily overlooked. As frequently as possible during the watch, back hourly files should be scanned and, before turning over the watch, a complete check of the back hourly files should have been made. The chances for errors are numerous, so constant checking and rechecking are the only means of assurance of delivery.

Messages are usually filed according to date on the morning following the day of origination of the traffic. After the files are bound, a final check for nondelivery should be made. If at any time a delayed or nondelivered message is found, the fact with the attendant circumstances should be reported in writing to the radio officer. Fear of the consequences must not be a factor in reporting the matter. Although such failures are serious, if an honest mistake has been made, punishment is seldom occasioned, and a rectification and report is essential to proper communication practice.

Messages requiring acknowledgments or replies within a definite time should be plainly indicated so as to bring that fact to the attention of the action officer. In addition, a tickler file kept by the supervisor will insure prompt acknowledgment or reply. If action is not taken within a reasonable, or specified time, the matter should be brought to the attention of the radio officer or the originator, as appropriate.

FREQUENCY SHIFTING

Since peacetime training is training for war, the time required for shifting frequencies is important. Generally, a time limit of 3 to 5 minutes is allowed for a frequency shift.

Usually frequency plans are standard, and in case of drills where frequency plans require channels not normally used, information is received well in advance of the time required. This permits time for necessary preparations—tuning of transmitters and setting up control lines.

At the beginning of hostilities a rigid radio silence is imposed so that all adjustments of transmitters and shifts of frequencies must be made without radiation. At the same time, transmitters and receivers must be tuned to the exact frequency in order to insure that other ships on the circuit will be able to receive the signals.

Receivers and transmitters usually have calibration cards attached which are periodically verified and corrected. However, many times frequencies not covered by the calibration chart are needed. Another thing, there is the matter of "frequency drift" which sometimes renders charts and curves nearly worthless. The one sure way of obtaining exact frequency settings is by intelligent use of the frequency meter. Supervisors become familiar with its use and make a routine event of checking the settings of receivers and transmitters. Proper use of the frequency meter assures accuracy within the limits of standard tolerance.

If rapid shifts with no advance information are necessary, the time required depends on the efficiency of the material personnel, the skill of the supervisor in using the frequency meter and his ability to handle control lines. Study your control system carefully, and with daily practice, assure yourself that use of the meter comes natural to you.

WATCH, QUARTER, AND STATION BILL

As a petty officer you should already have a thorough knowledge of your ship's watch, quarter and station bill. The information contained on the bill hardly needs review here. Since your seaman days you know that one of your first duties when you come aboard is to check the WQ&S bill to learn your battle station, fire station, fire and rescue station, your billet number, locker number, and so forth. (See fig. 218 for an example of a typical watch, quarter, and station bill.)

The radio officer, under the communication officer, is responsible for that portion of the bill which applies to radio spaces and radio personnel. However, he generally relies upon his leading petty officer—the traffic chief—to assist him in its preparation.

Fundamentally, the bill for all departments and sections aboard ship follows the same organization. In detail, applications of the bill vary with the specialties of the division. For this reason, considerable thought must be used when assigning your men.

First, get your bill squared away for Condition I, or general quarters. See that every circuit is manned by a battle-efficient operator. Assign "back-up" men in Radio II and III who will keep a duplicate log of traffic coming into radio central. If the communication plan calls for a CW operator on the bridge, assign a man who is thoroughly familiar with tactical procedures, especially the executive method. Don't make the mistake of concentrating your leading petty officers in one place. Assign operators to Radio II and III and bring maintenance men to radio central. Through careless assignment you could, for instance, risk the loss of all of your maintenance men by having them concentrated in or about a single compartment during battle.

Your selection of sound power-phone talkers is more important than it seems. If possible, use petty officers as talkers. They should be men able to talk distinctly, act quickly, and display at all times alertness and initiative. Be sure to have exceptionally good talkers assigned to the bridge and secondary conn.

When delegating men for duty in radio central in Condition I, be sure to provide enough messengers. During GQ emergency situations requiring messenger service constantly arise.

There are two points you should bear in mind, although they are not directly related to the watch, quarter, and station bill. During prolonged periods at GQ see that your men are rotated periodically, and see that they get their chow. Provision for the relief of operators can be made by sensible rotation from broadcast schedules to manual circuits, from active to dull circuits, and so forth. The time between rotations is a matter for your own judgment. Messengers and phone talkers can also be rotated to relieve the monotony of their billets. To get chow for your men, know what provision is made by the ship's organization to get food to the crew during long periods at GQ.

When preparing a bill for a three- or four-section watch, there are two important considerations. See that each section has a supervisor, and that enough operators are assigned to man all circuits. It may be necessary to use a split-phone watch when only a limited number of operators is available. Usually, split-phone watches are not indicated on the bill; this is a matter which the supervisor of the watch arranges.

Information concerning special stations such as fire, fire and rescue, collision, and abandon ship can be found in the ship's organization book. See that the organization book is complied with by the bill which you set up. In many instances your men will simply be designated to standby; but in some cases, such as abandon ship, each

1st. SECTION **WATCH, QUARTER AND STATION BILL** Q-R DIVISION

Billet No.	NAME	Rate All.	Rate Act.	Clean. Sta.	Battle Stations Cond. I	Cond. IE	Cond. II	Cond. III	Cond. A or Z	Cond. B or Y	Fire & Rescue	Fire	Abandon Ship Boat	Provide	Collision	Sea Detail	Spec. Det.	Landing Force	Gas Mask
110	A. J. Roth	RMC	RMC	←	IN	CHARGE		→			↑	↑	6			IN CHARGE			
111	D. Wilson	RM1	RM2	RAD I	SUP.	SUP.	SUP.	SUP.					2			SUP			
112	D. Cooke	RM2	RM2	RAD II	RAD II	RAD II	RAD II	RAD II					5			RAD II			
113	J. Hurley	RM2	RM3	VHF rm	RAD I	RAD I	RAD I	RAD I					6			RAD I			
114	C. Mann	TE2	TE3	RAD I	RAD I	RAD I	RAD I	RAD I					6			RAD I			
115	R. Nash	TE3	SN	RAD I	RAD I	RAD I	RAD I	RAD I					4			RAD I			
116	W. Norris	RM3	RM3	RAD III	RAD III	RAD III	RAD III	RAD III					4			RAD III			
117	C. Keefer	RM3	SN	RAD I	RAD I	RAD I	RAD I	RAD I			STANDBY	STANDBY	1			Bridge JX			
118	M. Adams	RM3	SN	RAD II	RAD II	RAD II	RAD II	RAD II					4			RAD II			
119	R. Wasner	RM3	SN	RAD III	RAD III	RAD III	RAD III	Bridge					2			Bridge			
1151	G. G. Davis	SN	SN	COMM CENTER	JX-RAD I	JX-RAD I	JX RAD I	RAD I					5			RAD I-JX			
1152	R. M. Carter	SN	SA	CRYPTO CENTER	HEADINGS	HEADINGS	HEADINGS	RAD I					5			RAD I			
1153	P. Heely	SA	SA	RAD I	MESSENGER		MESSENGER						6			Messenger			
1154		SA		RAD II	MESSENGER		MESSENGER	→					6			Messenger			
											↓	↓							

Figure 218.—The watch, quarter, and station bill.

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man will be assigned a definite station, and, more than likely, be required to bring certain items of equipment.

Finally, make a point of always keeping your watch quarter and station bill up to date.

THE TRAINING PROGRAM

One of the primary requirements of the RM first and chief is the ability to give adequate instruction in the classroom and on the job to other rated and nonrated men in the division. Besides having mastered your billet, you must be able to pass on the knowledge to your men. This is not always an easy matter, for there are many factors to be considered.

The training program is the direct responsibility of the radio officer and, under him, you must organize training material and schedules, select instructors, and supervise their teaching. This chapter will not attempt to cover every detail of administering shipboard training. You can find such information in the *Shipboard Training Manual,* NavPers 90110, and the *General Training Course for Non-rated Men* NavPers 10601. Study these two books carefully. They'll give you the basis for running the division training program. The purpose of the remainder of this chapter is to point out a few important things to keep in mind.

The two main purposes of a division educational program are (1) to school personnel in the operation of division equipment and the special skills demanded by the division watch and battle stations; and (2) to prepare men for advancement in rating. These two aims are closely related. Training men for advancement of rate will improve their skill in watch standing and vice versa. You should make the most of every opportunity for training your men. Almost every division activity can be used in instructing division personnel. As a general rule, men will learn the operation of equipment and the specialized technique most effectively through actual experience. Toward this end, organize the watch bill so that relatively inexperienced men are assigned stations where they can acquire these particular skills under the guidance of experienced petty officers. When possible, rotate them so that they have the chance to learn several different jobs. By pursuing this policy you can insure that there are at least two or more men qualified to handle each watch or battle station in case of emergency. In adopting a plan of watch rotation, remember that training is secondary to efficient performance of division duties and responsibilities.

In most cases the experience that men will gain in standing normal cruising watches will not be enough in itself to develop the specialized skills necessary for top efficiency. Consequently these skills must be developed during normal sea routine by a series of exercises. Regardless of the type of the exercise, its purpose remains the same: to develop to a high state of perfection the skill and techniques necessary to perform communication duties. Maximum efficiency is the result of constant hours of practice. Your men must be drilled and redrilled to the point that they can meet any battle emergency. You should organize a definite exercise schedule and ensure that it is strictly followed. A short intensive drill period daily is more effective than a long weekly drill. The amount of time that should be devoted to drill, depends upon the location of the ship and the general level of experience of men within the division. In combat zones, less time can be given to training exercises than in rear areas; similarly, an inexperienced division will require longer perods of drill to develop efficiency than will an experienced division to maintain it.

When time and conditions permit, an organized class schedule can be employed to round out a training program based on drill and directed experience. Each unit of instruction usually consists of two parts, knowledge and skill. The methods of presenting these two parts differ to such an extent that the time and place of instruction should be different. In both technical and operational training, the "knowing" or informational part of the unit is best presented through classroom group instruction methods. Except for a few all hands drills and evolutions, there will be parts of the division which can be scheduled in classroom work during operation and drill periods.

Closely related to the division training system whose purpose is to increase battle efficiency is the program leading to the advancement in rating of the men in the division. It is important that a regular system of selecting and training desirable men for promotion to higher rates be established. From the point of view of the Navy such a system will provide a steady flow of well-qualified petty officers capable of accepting responsibilities; from the viewpoint of the men under you the system offers the opportunity of increase in pay and authority as a direct result of their own ambition and initiative. Generally the same training program will serve the dual purpose of promoting communication efficiency and preparing communication personnel for advanceent in rating. Bear in mind, however, that technical skills are only one factor in advancement of rating. Men who are advanced to petty officers must be capable of leadership and initiative. In short, a man may be a highly skilled radio operator and still be lacking in the qualities necessary to be a good petty officer.

CHARACTERISTICS OF A GOOD TRAINING PROGRAM

Any shipboard communication training program must be judged by three basic standards—flexibility, motivation, and simplicity.

The program must be flexible. It must be arranged so that it will meet immediate needs and will change as the needs change. It must function effectively and take advantage of unforeseen opportunities, such as power failure, equipment failures and other incidents that afford a variety of training.

The program should encourage initiative on the part of the instructor and the student by motivating the men in the division to an enthusiastic reception of the training program and by recognizing individual merit. Under any conditions men acting as instructors must be given ample time to prepare new material for presentation and to plan in advance for the next lesson.

Finally, the program must be a model of simplicity. Provision must be made to keep records and reports at a minimum, make materials accessible, keep policy understandable, and to use the least complex scheduling system. Results are what count.

COMMUNICATION TRAINING PORTFOLIO

A written communication training portfolio will prove a useful aid in standardizing the operating procedures developed and tested in the communication department. These procedures will vary from ship to ship according to the gear installed and men available. Since this portfolio will normally describe the individual duties and stations it will be valuable in training new men and in carrying out the fundamental training policy of rotating members of the gang among the various stations. The training portfolio would normally include the following detailed items:

1. A list of each person or position in the radio gang during general quarters, condition watches, normal cruising watch, and flight quarters.

2. A detailed list of the duties of each person in the above conditions.

3. Detailed instructions as to the procedures and techniques for carrying out these assigned duties.

4. Assignment of specific communications circuits for each station listed in item 2.

5. Instructions for the arrangement of training exercises other than scheduled fleet training exercises, including methods by which training may be carried out while underway or in port according to a schedule consistent with operational duties.

Training within the radio gang should be devoted to establishing and maintaining complete operational familiarity and competence in all functions assigned and the procedures involved. Instructions should be held on the following subjects:

1. Communication equipment maintenance routines.
2. *Joint Communication Instructions.*
3. Touch typing.
4. International Morse Code.
5. Receiver tuning.
6. Transmitter tuning.
7. Correct use of the frequency meter.
8. Operation of the RDF.
9. Use of testing equipment.
10. Radio telephone procedure.
11. Communication and operation plans.
12. New equipment in the fleet, even though not presently installed on own ship.
13. Casualty procedures: main power, remote units, interior and exterior communication facilities, etc.
14. Fundamentals of underwater sound equipment.
15. Wave propagation.
16. Antennas.
17. Basic navigation.
18. Abstracting and accounting.
19. Vacuum tubes.
20. Motors and generators.
21. Communication systems.
22. Teletype equipment.
23. Supervision and watches.

Training should include exercises that tend to establish and maintain a high standard of performance in carrying out communication duties. A representative list of such drills follows:

1. Tuning, calibration, and adjustment of transmitters and receivers.
2. Actual operation of the RDF.
3. Examinations of classroom studies.
4. Operating from emergency positions.
5. Intraship drill circuits.
6. Fleet drill circuits.

QUIZ

1. Who is primarily responsible for keeping traffic clear and maintaining discipline in the radio room?
2. How do supervisory duties increase on a small vessel?
3. What precaution regarding radio room publications should the supervisor take before accepting the watch?
4. What information should the supervisor keep posted at operating positions in order to assist his men?
5. How does the supervisor determine who is authorized to release outgoing messages?
6. Why is it important that the supervisor determine times of peak traffic loads?
7. What is the procedure for reporting a delayed or nondelivered message?
8. What is the purpose of the tickler file?
9. What preparations can the supervisor make for anticipated frequency shifts?
10. What is the purpose of a progress chart?
11. When setting up a watch quarter and station bill, to what condition should you first assign your men?
12. If the watch quarter and station bill requires a CW operator on the bridge for general quarters, what precaution should you take in assigning the operator?
13. What is the value of developing training consciousness among your petty officers?
14. What important consideration can be given men who are slow in learning a particular subject?

APPENDIX I

ANSWERS TO QUIZZES

CHAPTER 1

COMMUNICATION SYSTEMS

1. The mission of the Naval Communication Service is to provide reliable, speedy, and accurate communications to serve Command and Administration.
2. Joint communications includes those communication doctrines and procedures jointly promulgated for use of all branches of the Armed Forces.
3. The five primary communication centers are located in Washington, D. C. (NSS); San Francisco (NPG); Honolulu (NPM); Guam (NPN); and Balboa (NBA).
4. NTX is the Naval Teletypewriter System. TWX is the Teletypewriter Exchange Service furnished by the telephone company.
5. Joint communications are controlled by the Joint Communications-Electronics Committee (JCEC).
6. The three ZONES of Army communications are: zone of the interior, communication zone, and combat zone.
7. ACAN is the Army Command and Administrative Network.
8. The Chief Signal Officer in the Army holds a position which corresponds to DNC.
9. The Army organizes and maintains special teams for installation of unusual or special equipment.
10. The division is the smallest unit to which Signal Corps troops are normally assigned.
11. The principal Air Force communication network is Airways and Air Communication Service (AACS).
12. Air Force communication unit commanders assist and advise the Air Force Communications Officer.
13. The most important method of transmitting traffic between Coast Guard shore stations and ships is the receipt (R) method.
14. The district commandant is responsible for communications within a Coast Guard district.

15. The Federal Communication Commission was created by an act of Congress—the Communications Act of 1934.
16. There are seven FCC commissioners.
17. The FCC makes no charge for its licensing activities.
18. Even though FCC monitors broadcasts, it has no power to censor radio programs.

CHAPTER 2

RADIO WAVE PROPAGATION

1. The exact frequency to be used to communicate with another station depends upon the condition of the ionosphere and upon the distance between stations.
2. The standard band for naval communications lies between 2000 and 18100 kilocycles.
3. The ionosphere acts as a conductor, absorbs energy, and refracts or bends the sky wave back to earth.
4. The D-layer is only present during daylight hours.
5. The four parts of a ground wave are: direct, ground-reflected, tropospheric, and surface waves.
6. The ionosphere is located in the rarified atmosphere, approximately 30 to 350 miles above the earth.
7. At night, the sky wave provides a means for long-range contacts.
8. The conductivity of salt water is 5,000 times as great as that of dry soil.
9. The surface wave extends a considerable distance up into the air, but it drops in intensity as it rises.
10. The critical frequency is the highest frequency which the ionosphere will reflect back to the earth.

CHAPTER 3

ANTENNAS

1. The purpose of checking nonresonant transmission lines is to see if there are any standing waves present.
2. The two parts of directional antenna systems are the radiator and the reflector.
3. A standing wave is the result of a certain amount of energy being reflected back along the transmission line.
4. The electrical length of the antenna must be changed each time the frequency of the transmitter is changed.

5. The four general types of transmission lines used with frequencies below 300 mc. are the open two-wire system, coaxial cable or concentric line, twisted pair and the shielded pair.
6. The quarter-wave antenna is used extensively with portable equipment.
7. On board ship other antennas mean any antenna on board a ship moored alongside, across a pier, or at nearby shore radio stations.
8. The pressurized concentric line will work well with frequencies up to 300 mc.
9. The twisted pair transmission line is the least efficient.
10. The gain of the rhombic antenna depends on the design and the length of its legs.

CHAPTER 4

VACUUM TUBES

1. The two general types of characteristic curves for triodes are the static curve and the dynamic curve.
2. The simplest type of vacuum tube is the diode.
3. The triode differs in construction from the diode only in the addition of another element, called the grid.
4. The simplest method of obtaining negative grid bias for a triode is fixed bias from a battery or rectifier power supply.
5. The beam-power tube compared with other tetrode and pentode power-amplifier tubes has the advantage of higher power output, higher power sensitivity, and higher efficiency.
6. The diode contains two elements. They are the cathode and plate.
7. The two types of cathodes or emitters used in radio tubes are the filament or directly heated type and the indirectly heated type.
8. The ability of a diode to conduct, or pass, current in only one direction makes possible its use as a rectifier to convert alternating current into direct current.
9. To convert rectified alternating current into pure direct current, the fluctuations must be removed.
10. The disadvantage of the half-wave rectifier is that no current flows during the negative half-cycle.
11. The full-wave rectifier is so called because it rectifies on both half-cycles.

12. The amplification factor of a tube gives a theoretical approximation of the maximum voltage amplification which can be expected from the tube under given operating conditions.
13. The plate resistance of a tube is simply the resistance between the cathode and plate of the tube to the flow of alternating current.
14. The fourth element or screen grid is placed between the grid and the plate of the tetrode.

CHAPTER 5

RECEIVERS

1. Resistors are generally classified as wire wound or composition.
2. Tuned r. f. amplifier increase the selectivity and the sensitivity of t. r. f. receivers.
3. The chief disadvantage of the t. r. f. receiver is that its selectivity (ability to separate signals) does not remain constant over its tuning range.
4. A check of the receiver alinement is a necessary step upon completion of neutralization.
5. Trimmers should never be forced because there is always a possibility of stripping the threads.
6. A measurement of the receiver sensitivity, with good tubes, is an excellent test to determine whether the receiver is in need of alinement.
7. The two most widely used detector circuits are the diode detector and the power detector.
8. To increase the amount of band spread the small capacitor may be tapped down on the coil, so that it uses only a small portion of the coil.
9. The voltage divider regulates the current.
10. Coupling between two circuits is prevented by using metal shields which are grounded to the chassis.

CHAPTER 6

THE SUPERHETERODYNE RECEIVER

1. Automatic volume control is widely used in superheterodyne receiver.

2. When r. f. amplifiers are used in superheterodyne receivers, they are called preselectors.
3. The sensitivity required determines the number of i. f. amplifier stages used in a superheterodyne receiver.
4. The combined circuits of the oscillator stage and mixer stage form the frequency converter of the superheterodyne receiver.
5. To aline a superheterodyne, you will need a test oscillator, output meter, nonmetallic alining tools and sometimes a dummy antenna.
6. The intermediate frequency stages, the local oscillator, and the preselector stages of a superheterodyne receiver must be correctly tuned or alined before the receiver will function properly.
7. A pentagrid converter is a tube which has the oscillator and frequency mixer combined and also has five grids.

CHAPTER 7

TESTING EQUIPMENT

1. The purpose of a frequency meter is to measure the frequency of transmitters, receivers, and other oscillating circuits.
2. One of the greatest errors resulting in the use of the ohmmeter, is the failure to zero center the needle with the test prods short-circuited before making a measurement.
3. An understanding of the correct use of voltmeters, ohmmeters and other equipments not only speeds repair but also protects the instruments from injury due to improper handling.
4. Alternating current voltmeters of the rectifier type should be used when measuring a. c. voltage.
5. The signal generator is used when making receiver alinement and sensitivity measurements.

CHAPTER 8

TRANSMITTERS

1. Overheated tubes usually indicate improper tuning, a short-circuited or open antenna circuit, improper bias or a poor tube.
2. When tuning seems faulty the trouble will usually be found in the tuned circuits themselves.

3. A bleeder resistor should never be trusted to drain a filter condenser of its charge because it may open up and cause you to get a fatal shock.
4. The purpose of safety or door interlocks is to prevent personnel from gaining access through the doors, to the compartments in a transmitter without first removing all dangerous voltages from the transmitter circuits.
5. The oscillator tube is usually supplied with power from a separate armature or rectifier to insure frequency stability.
6. When the antenna has been tuned to approximate resonance it will be found that the power amplifier plate current will begin to rise.
7. When the electron-coupled oscillators are properly designed and operated the frequency stability compares very favorably with the crystal-controlled oscillator.
8. Pure grain alcohol is the most desirable cleaning agent.
9. Care must be exercised when removing the crystal from its holder so as not to chip or crack the crystal.
10. Most trouble experienced in tuning HF transmitters is usually caused by insufficient knowledge of the transmitter circuits and the process of frequency doubling.
11. When an antenna is fed through a trunk the antenna current reading at the transmitter will not be the same as that at the base of the antenna proper.
12. The purpose of using stand-by operation of rectifier filaments is to eliminate the 30-second wait before rectifier plate voltage can be applied.
13. Before making an ohmmeter test on filter condensers always short-circuit and ground them.
14. Dirty contacts on tuning coils or condensers will cause the plate current meter to flicker when tuning through resonance.
15. Quick acting overload relays are used in the plate circuits of transmitting tubes.
16. The purpose of the transmitter frequency chart is to enable any inexperienced operator to reset the transmitter to a given frequency in the shortest possible time.
17. The function of the electrostatic shield is to prevent disturbances in the power line from reaching tube circuits. It also prevents transient high frequency oscillation from the equipment from feeding back into the power line.
18. The purpose of any rectifying device is to convert or change alternating current into a pulsating direct current.

CHAPTER 9

RADIOTELEPHONY

1. The modulator furnishes the power necessary to vary the amplitude of the r. f. wave in accordance with the sound impulses.
2. The speech amplifier is used to raise the audio output of the microphone to a suitable level for use in the modulator stage.
3. The carbon microphone is the most widely used in the Navy.
4. The amount of power required to modulate a transmitter depends on the percent and type of modulation.
5. Plate modulation is used to a greater extent in the Navy than any other.
6. Amplitude modulation may be defined as the variation of the strength of the r. f. output of a transmitter at an audio rate.
7. Suppressor grid modulation is usually found in naval aircraft transmitters.
8. The reason for varying the plate voltage of the r. f. amplifier is to vary the power output of the transmitter.
9. The microphone generates an audio signal.
10. The simplest method of modulating the plate of the r. f. amplifier is by means of a transformer coupling.

CHAPTER 10

SONAR EQUIPMENT

1. SEARCHLIGHT sonar is a type which transmits sound as an underwater beam, and is highly directional in nature.
2. Integrated sonar uses a special depth-determining transducer which can be depressed, thus giving the slant range of the submarine. From this, the depth of the sub is determined.
3. This information is provided by the attack director.
4. The antisubmarine attack run is normally conned by the ASW officer.
5. Originally, various units of the remote control unit were literally stacked one on the other; hence, the term "stack."
6. The transducer changes the electrical energy from the driver into mechanical energy of sound waves when a transmission is made. It is located in a dome beneath the keel of the ship.

7. The attack plotter provides own ship's track, own ship's sound beam, submarine's track, and a predictor line.
8. Every fathometer has a transmitter, receiver, and a depth recorder.
9. The fathometer recorder gives a continuous and permanent record of all soundings received while the instrument is in operation.

CHAPTER 11

MOTORS AND GENERATORS

1. Slotted commutators should have their slots cleaned out as an insurance against bridging between segments.
2. The commutator is a smooth chocolate color when in the normal operating condition.
3. If the contacts are burned, smooth them down with a file or renew them as occasion demands.
4. The existence of grounded coils may be determined by reading the armature resistance to ground with a megger.
5. A bright spark appearing under one brush and gradually cutting a groove in the commutator is due to a particle of copper which has become embedded in the brush.
6. The commutator should be kept clean by wiping with a light canvas, cheesecloth, or woolen cloth. Care must be taken not to allow any threads to lodge on the brushes or between the segments.
7. Sparking at the brushes indicates a condition which should be promptly remedied to prevent serious trouble.
8. Fuses can be considered a source of trouble if they are not used and replaced intelligently.
9. Switch clips should be kept smooth and tight to insure good contact when the switches are closed.

CHAPTER 12

TELETYPEWRITER EQUIPMENT

1. The synchronous motor requires a steady 60-cycle current.
2. The switching arrangement on the model 19 set provides for direct keyboard transmission only, tape perforation only, or simultaneous direct keyboard transmission and tape perforation.

3. The primary function of a teletypewriter keyboard transmitting unit is the transformation of mechanical motion into electrical impulses of the five-unit code for transmission to receiving stations.
4. Saw-toothed shaped notches on the selector bars are used to move the bars left to right (marking or spacing) when a key is depressed.
5. When installing a typing unit, care should be taken not to jam the bakelite main shaft gear against the motor pinion.
6. The REC–13 is a dry disk rectifier, and the REC–30 operates with a vacuum tube. The REC–13 can be used only for 60 cycle a. c. operation.
7. When it is necessary to use the maximum regulating tap to obtain the proper output current on the REC–13, the rectifier should be withdrawn from service and repaired.
8. The outer distributor ring is divided into seven segments. Segments Nos. 1 to 5 (between the START and the STOP segments) are used to transmit intelligence.
9. Overlubrication of teletypewriter equipment results in the accumulation of dirt and grit in the machine, causing excessive wear and deterioration, and constitutes a fire hazard.
10. Grease is packed about a motor bearing before the motor is assembled. An attempt to inject grease into a bearing after the motor is assembled will result in overflow of grease to other parts of the motor.

CHAPTER 13

ABSTRACTING AND ACCOUNTING

1. COMLE is an indicator meaning commercial. It is used after the service indicator or after the CK in a class E message that is refiled with Western Union.
2. SRS numbers are serially numbered from 1 to 10,000. NR numbers are kept on a daily basis. SRS numbers are never transmitted over a circuit; NR numbers are.
3. Western Union rate tables list charges for full rate fast telegrams.
4. The name and rank of the sender are the items in the signature of a class E message which are not counted.
5. Communication Circular Letter I–47 provides special tables which convert full telegram rates to day or night letter rates.

6. The form used for abstracting class E traffic is the abstract of Class E Messages Sent.
7. Class E messages sent from a ship are grouped on the abstract according to the shore radio station which accepted them. About 10 lines should be allowed between stations.
8. Form NCS 235 is always forwarded with an abstract when money has been collected.
9. Tolls collected may be forwarded as a money order, or as a supply officer's check. Cash, personal checks, or stamps are not acceptable.
10. When tolls are due Western Union the supply officer's check (or money order) is made payable to the Western Union Telegraph Company, Washington, D. C. It is forwarded to the chief of Naval Operations (DNC).
11. An error notice is a form sent out by NCS when a ship or station has made an error in collecting tolls. The two types are SHORT COLLECTION and OVER COLLECTION notices.
12. One copy of the error notice is signed and immediately returned to NCS. The second copy is placed on file in the ship or station.
13. The maximum amount of money allowed to accumulate in the NCS fund before it is turned over to the supply officer is $100.
14. Radiotelegrams and cablegrams are always sent in international commercial form.
15. Form 233 is used for incoming class D traffic, and form 234 for outgoing.
16. Government messages, press, and direct ship-to-ship messages are tax free.
17. A GOVT NAVY message is class A.
18. When a naval form message is placed in the text of a commercial message, pronounceable call signs are transmitted as they are. Call signs which cannot be pronounced are transmitted in the phonetic alphabet.

CHAPTER 14

NAVIGATION

1. Generally speaking, navigation is divided into celestial navigation and piloting.
2. The gyrocompass depends upon an outside mechanism for its operation; the magnetic compass requires only the earth's magnetic field.

3. VARIATION at any point on the earth is the difference between magnetic north and geographic north at that point.
4. DEVIATION is caused by the force of the ship's magnetism upon the magnetic compass.
5. When you change true course to compass course you are UNCORRECTING.
6. The correct name for a "dumb compass" is pelorus.
7. Distances between points on a chart can be determined by measuring them against the latitude scales.
8. One minute (1′) of latitude is equal to one nautical mile.
9. A compass rose is a circle scaled to 360° which appears on charts as a reference for bearing data.
10. A fathom curve is a line drawn on a chart along the points where the depth of the water is the same number of fathoms.
11. The letters *C*, *N*, and *S* indicate types of buoys: can, nun, and spar.
12. The label for any line should lie along the line.
13. Loran measures the time of arrival of radio waves, and r. f. d. equipment measures the direction.
14. When several loran stations transmit on the same frequency, each pair of stations operates on a different pulse-recurrence rate.
15. Bouncing between the earth and ionosphere alters the travel time of a radio wave, rendering it inaccurate for loran use until compensation is made.
16. Each pair of loran stations is given a three-character identification symbol known as THE RATE.

CHAPTER 15

SUPERVISION AND WATCHES

1. The responsibility for keeping traffic clear and maintaining discipline in the radio room is mainly the concern of the supervisor of the watch.
2. Usually a small vessel has no communication watch officers. Consequently, the supervisor assumes the duties of a CWO.
3. The supervisor should make a sight-check of all radio room publications before relieving the watch.
4. The supervisor should see that special calls, authenticators, and other information required by the operator is posted at each operating position.
5. The names of persons authorized to release outgoing messages are furnished the supervisor by the radio officer.

6. The supervisor must determine times of peak traffic loads in order to plan his work in a manner that prevents unnecessary backlogs of messages during periods of heavy traffic.
7. The report of a delayed or nondelivered message should be made by the supervisor to the radio officer in writing.
8. The tickler file is a means of keeping tab on messages requiring acknowledgments or replies within a definite period of time.
9. The supervisor can set up spare equipments, if available, and make intelligent use of control lines.
10. As the name implies, progress charts show the trainee's advancement. They are filled in by the petty officer in charge of the trainees and submitted to the division officer.
11. When setting up a watch quarter and station bill, assign your men to Condition I, or general quarters, first.
12. Before assigning a CW operator to the bridge, be sure he knows tactical procedures, especially the executive method.
13. Petty officers who are training conscious will see opportunities for practical training in nearly every shipboard activity.
14. Men who are slow in learning a particular subject should be included as often as possible in the classes covering the subject.

APPENDIX II

QUALIFICATIONS FOR ADVANCEMENT IN RATING

RADIOMEN (RM)

RATING CODE No. 250

General Service Rating

Radiomen operate radios, radio-direction finders, teletypewriters, and voice-radio equipment. Transmit and receive messages by International Morse Code and type incoming messages. Make operational adjustments to and perform upkeep on equipment.

Emergency Service Ratings

Title	Abbr.	Rating Code No.	Definition
Radiomen N	RMN	251	Same as General Service Rating. Do not use American Morse Code.
Radiomen T	RMT	252	Operate key telegraph and use American Morse Code.

Naval Job Classifications

Group Code Nos.	Group Titles	General Service	Emergency Service	
		RM	RMN	RMT
21500–21599	Radio repairmen	X	X	....
24100–24199	Radio supervisors	X	X	....
24200–24299	Radio operators, radio watch	X	X	....
24900–24999	Radio operators, basic	X	X	....
27000–27999	Telegraphers	....	....	X
72800–72899	Teletypewriter operators	X	X	X

Qualifications for Advancement in Rating

Qualifications for Advancement in Rating	Applicable Rates		
	RM	RMN	RMT
	250	251	252
.100 PRACTICAL FACTORS			
.101 OPERATION			
Obtain bearings with radio direction finder in own ship or station	3,2,1,C	3,2,1,C	....
Operate manual and automatic teletypewriters	3,2,1,C	3,2,1,C	3,2,1,C
Operate, calibrate, and adjust all standard naval radio, radio-direction-finder, and emergency and portable radio equipment aboard own ship or at station	1,C	1,C	....
.102 WATCHES			
Stand watch on a voice radio circuit	3,2,1,C	3,2,1,C	....
Stand watch on an 18 w.p.m. fleet circuit and copy standard Fox broadcast, keeping traffic, circuit-failure, and other required logs	3,2,1,C	3,2,1,C	....
Stand watch on a 20 w.p.m. teletypewriter circuit and an 18 w.p.m. International Morse circuit	3,2,1,C	3,2,1,C	....
Stand watch on a 20 w.p.m. teletypewriter circuit and an 18 w.p.m. American Morse telegraphy circuit	....	....	3,2,1,C
Stand watch on any fleet circuit	2,1,C	2,1,C	....
Stand watch on a 25 w.p.m. teletypewriter circuit and a 20 w.p.m. International Morse circuit	2,1,C	2,1,C	....
Stand watch on a 25 w.p.m. teletypewriter circuit and a 20 w.p.m. American Morse telegraphy circuit	....	....	2,1,C

Qualifications for Advancement in Rating	Applicable Rates		
	RM	RMN	RMT
	250	251	252
Take charge of watch; act as supervisor and perform duties of senior radio telegrapher or radioman, as applicable	1,C	1,C	1,C
Stand watch on a 40 w.p.m. teletypewriter circuit and on a 25 w.p.m. International Morse circuit	1,C	1,C	....
Stand watch on a 40 w.p.m. teletypewriter circuit and on a 30 w.p.m. American Morse telegraphy circuit	....	....	1,C
.103 OPERATING ADJUSTMENTS			
Start, stop, regulate, and make necessary operating adjustments on naval radio transmitting and receiving equipment in own ship or station, observing all safety precautions	3,2,1,C	3,2,1,C	....
.104 MAINTENANCE AND REPAIR			
Lubricate, clean, and detect mechanical defects in:			
Radios	3,2,1,C	3,2,1,C	....
Teletypewriters	3,2,1,C	....	3,2,1,C
Perform simple emergency repairs to:			
Radios	2,1,C	2,1,C	....
Teletypewriters	2,1,C	....	2,1,C
Adjust, calibrate, and perform upkeep on radio and radio-direction-finder equipment	1,C	1,C	....
Install teletypewriter equipment	1,C	....	1,C
Supervise upkeep of radios and radio equipment	C	C	....
Supervise assembly, disassembly, and repair of teletypewriters	C	....	C

Qualifications for Advancement in Rating	Applicable Rates		
	RM	RMN	RMT
	250	251	252
.105 ANTENNAS			
Rig emergency radio receiving and transmitting antennas	3,2,1,C	3,2,1,C	....
.106 COMMUNICATIONS AND TRAFFIC HANDLING			
Use signs, prosigns, and operating signals in handling traffic	3,2,1,C	3,2,1,C	3,2,1,C
Route traffic to, from, and within own ship or station	2,1,C	2,1,C	2,1,C
.107 SWITCHBOARD			
Operate a teletypewriter switchboard and make patches in the circuit	1,C	....	1,C
.108 ELECTRICITY			
Rig a practice buzzer circuit as required. Operate and care for a.c. and d.c. motors and generators	2,1,C	2,1,C	....
.109 SUPERVISION			
Supervise and train personnel engaged in:			
Radio duties	1,C	1,C	....
Telegraphy duties	....	....	1,C
Organize, direct, and supervise a radio station aboard ship or ashore	1,C	1,C	....
Supervise a teletypewriter office	1,C	1,C	1,C
Supervise a telegraph office	....	....	1,C
.200 EXAMINATION SUBJECTS			
.201 TRANSMITTING AND RECEIVING			
Transmit and receive according to standard tests described in operating tests below. (See .401, .402, .403.)	3,2,1,C	3,2,1,C	3,2,1,C

Qualifications for Advancement in Rating	Applicable Rates		
	RM	RMN	RMT
	250	251	252
.202 TYPEWRITING			
Qualify in touch typewriting on a telegraphic typewriter, and a teletypewriter	3,2,1,C	3,2,1,C	3,2,1,C
.203 FIRST AID			
First aid, with emphasis upon treatment for personnel suffering from electric shock and burns	3,2,1,C	3,2,1,C	3,2,1,C
.204 ELECTRICITY			
Types, uses, care, and maintenance of batteries in naval communications	3,2,1,C	3,2,1,C	3,2,1,C
Electron theory and magnetism	3,2,1,C	3,2,1,C	1,C
Simple problems in a.c. and d.c. radio circuits and in a.c. and d.c. motors and generators	1,C	1,C	....
Reading of wiring diagrams and blueprints. Interpretation of radio symbols	2,1,C	2,1,C	2,1,C
.205 OPERATING PROCEDURES			
Procedure for communicating with a ship or aircraft in distress	3,2,1,C	3,2,1,C	....
Operating procedures, communication instructions, and naval organization as set forth in JANAP and USF communication instructions	3,2,1,C	3,2,1,C	3,2,1,C
Commercial traffic instructions	3,2,1,C	3,2,1,C	3,2,1,C
International radio procedure. Regulations regarding communications as prescribed for the safety of life at sea and communication with a merchant vessel at sea	3,2,1,C	3,2,1,C	....
Current fleet radio doctrine	2,1,C	2,1,C	....

Qualifications for Advancement in Rating	Applicable Rates		
	RM	RMN	RMT
	250	251	252
.206 FREQUENCIES			
Frequencies assigned for general naval use	3,2,1,C	3,2,1,C	....
.207 SECURITY			
Principles of and requirements for maintenance of communication security	3,2,1,C	3,2,1,C	3,2,1,C
.208 TELETYPEWRITER, RADIO, AND ASSOCIATED EQUIPMENT			
Characteristics (operation, adjustment, maintenance and care) and nomenclature of various types of:			
Radio and radio-direction-finder (including HFDF) equipment on own ship or at own station	2,1,C	2,1,C	....
Teletypewriter equipment at own station	2,1,C	2,1,C	2,1,C
.209 ANTENNAS			
Characteristics of various types of antennas used aboard ship	2,1,C	2,1,C	....
Design of all types of antennas in general use for radio communications	C	C	....
.210 EMERGENCY AND PORTABLE EQUIPMENT			
Routine care and operation of emergency and portable equipment, including internal-combustion engines	2,1,C	2,1,C	....
.211 COMMERCIAL PRACTICES			
Commercial accounting and abstracting as used by the Navy	1,C	1,C	1,C

Qualifications for Advancement in Rating	Applicable Rates RM 250	RMN 251	RMT 252
.212 COMMUNICATIONS SYSTEMS			
Organization, functions, and facilities of the Navy, Army, Air Force, Coast Guard, and U. S. commercial communications systems. Basic rules and regulations of the Federal Communications Commission	1,C	1,C	1,C
.213 TRAFFIC CONTROL			
Precedence classification of traffic, clearing of traffic, and maintenance of circuit discipline within the net	3,2,1,C	3,2,1,C	3,2,1,C
.214 TELEGRAPHY			
Regulations governing American Morse telegraphy circuits at own station	....	....	3,2,1,C
.215 VACUUM TUBES			
Theory and use of vacuum tubes currently employed in naval communications equipment	1,C	1,C	....
.216 RADIO DIRECTION FINDERS			
Theory of operation of radio-direction-finders and loran	3,2,1,C	3,2,1,C	....
Installation, correction, and compensation of standard types of naval radio-direction-finders (including HFDF equipment)	1,C	1,C	....
.217 WAVE PROPAGATION			
Theory of wave propagation, including knowledge of skip distances, sky-wave and ground-wave effects, the ionosphere, and the sunspot cycle and its effect on wave propagation	2,1,C	2,1,C	....

Qualifications for Advancement in Rating	Applicable Rates		
	RM	RMN	RMT
	250	251	252
.218 SONAR EQUIPMENT			
Operating characteristics of standard naval types of sonar equipment	C	C	....
.219 NAVIGATION			
Charts, dead reckoning, and methods of determining position	1,C	1,C	....
.220 SAFETY PRECAUTIONS			
Safety precautions to be observed in the operation and care of electrical equipment	3,2,1,C	3,2,1,C	3,2,1,C
.221 PUBLICATIONS			
Use of major publications and manuals pertaining to naval, commercial, and international communications procedure	3,2,1,C	3,2,1,C	3,2,1,C
.222 ORGANIZATION			
Standard departmental organization of a ship	3,2,1,C	3,2,1,C	3,2,1,C
.300 NORMAL PATH OF ADVANCEMENT TO WARRANT GRADE			
Radiomen advance to Warrant RADIO ELECTRICIAN 7621 (Communications Supervisor). They act as Assistant Communications Officers or Communications W. O., in communications offices afloat and ashore.			
.400 TESTS (Radio, Teletypewriter, International Morse and American Morse Telegraphy).			
.401 RADIO (International Morse) (TIME limit—eight minutes each for transmitting and receiving tests) (for RM & RMN).			

Qualifications for Advancement in Rating	Applicable Rates		
	RM	RMN	RMT
	250	251	252
Transmit and receive a file of:			
3 messages	3	3	....
4 messages	2	2	....
5 messages	1,C	1,C	....
in Class A form, each file containing a total of:			
500 characters	3	3	....
600 characters	2	2	....
700 characters	1,C	1,C	....
of which			
2 messages	3	3	....
3 messages	2	2	....
4 messages	1,C	1,C	....
shall be composed of five-letter groups, the letters random mixed, and one message shall be composed of random mixed numeral-letter code in groups of five characters.			
.402 TELETYPEWRITER (TIME limit —six minutes to complete transmitting test) (for RM, RMN, RMT).			
Transmit a file of:			
3 messages	3	3	3
4 messages	2	2	2
5 messages	1,C	1,C	1,C
in Class A form, containing a total of:			
600 characters	3	3	3
750 characters	2	2	2
1,200 characters	1,C	1,C	1,C
of which			
2 messages	3	3	3
3 messages	2	2	2
4 messages	1,C	1,C	1,C
shall be composed of five-letter groups, the letters random mixed, and one message shall			

Qualifications for Advancement in Rating	RM 250	RMN 251	RMT 252
be composed of random mixed numeral-letter code in groups of five characters.			
.403 AMERICAN MORSE TELEGRAPHY (TIME limit—eight minutes each for transmitting and receiving tests) (for RMT).			
Transmit and receive a file of:			
3 messages			3
4 messages			2
5 messages			1,C
in Class A form, each file containing a total of:			
425 characters			3
525 characters			2
600 characters			1,C
of which			
2 messages			3
3 messages			2
4 messages			1,C
shall be composed of five-letter groups, the letters random mixed, and one message shall be composed of random mixed numeral-letter code in groups of five characters.			

STANDARD TEST PROCEDURE

The following standard procedure shall be used in giving tests under .401, .402, and .403 above:

MESSAGES

Messages shall be approximately the same length, heading containing about 30 percent and the text about 70 percent of the total number of characters. One complete rehearsal immediately preceding the official test is permissible. The messages used for the official test must differ from those used for the rehearsal, and must be unknown to the applicant before the test starts. Time limits for the complete tests shall include "servicing" each message by endorsing thereon the time of transmission or reception, circuit used, and operator's sign.

TRANSMITTING (International Morse, Teletypewriter, American Morse)

All known errors must be corrected.

A total of five errors (uncorrected or omitted characters) will be permitted in transmitting in any complete test.

RECEIVING (International Morse and American Morse)

Receiving shall be done on a telegraphic typewriter. Five errors will be permitted in receiving in any complete test.

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