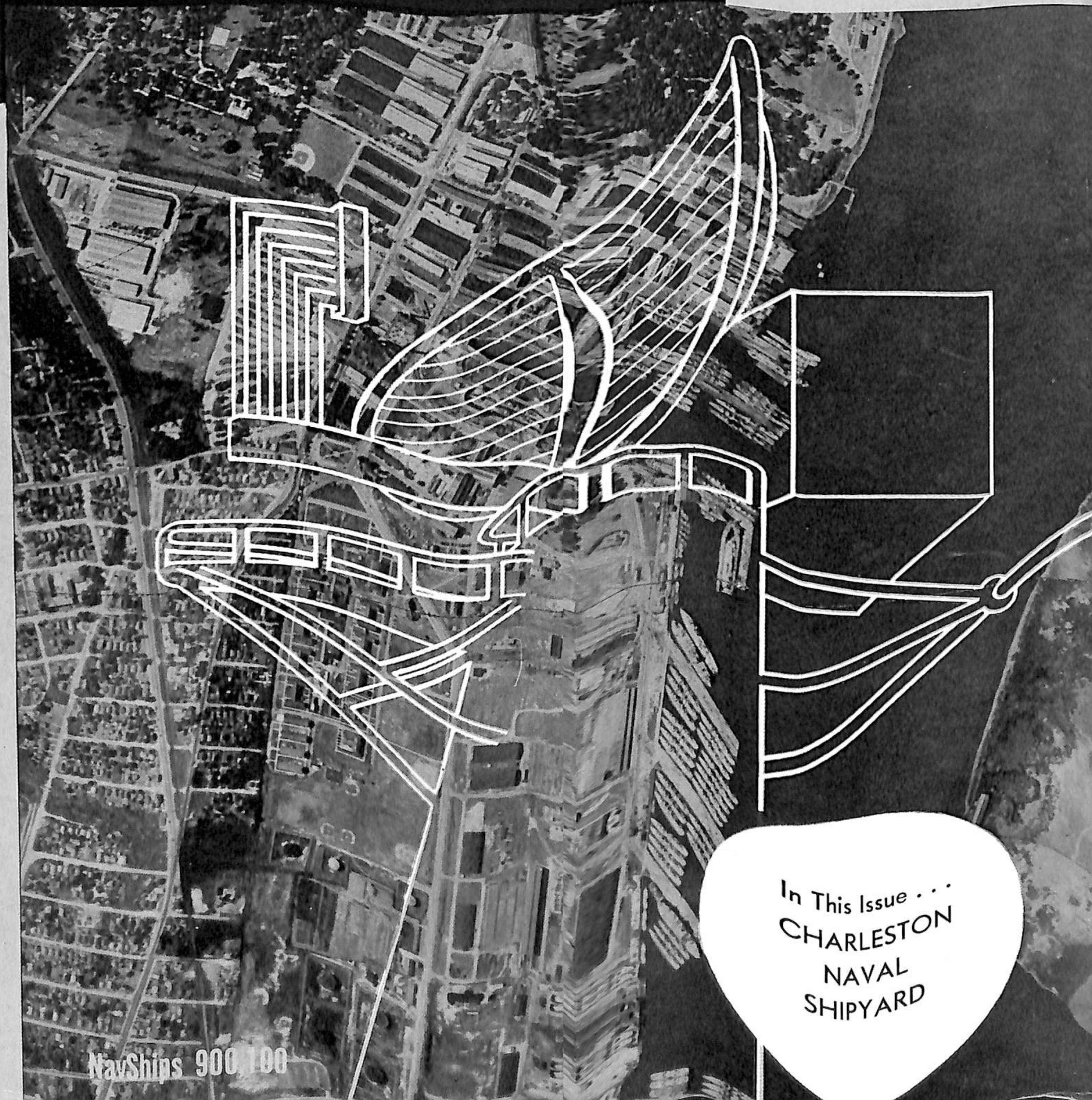
RESTRICTED

# BUSHIPS Electron

SEPTEMBER
1949



In This Issue . . .
CHARLESTON
NAVAL
SHIPYARD

NavShips 900,100

RESTRICTED

BUSHIPS Electron

A MONTHLY MAGAZINE FOR
ELECTRONICS TECHNICIANS

SEPTEMBER · VOLUME 5 · NUMBER 3

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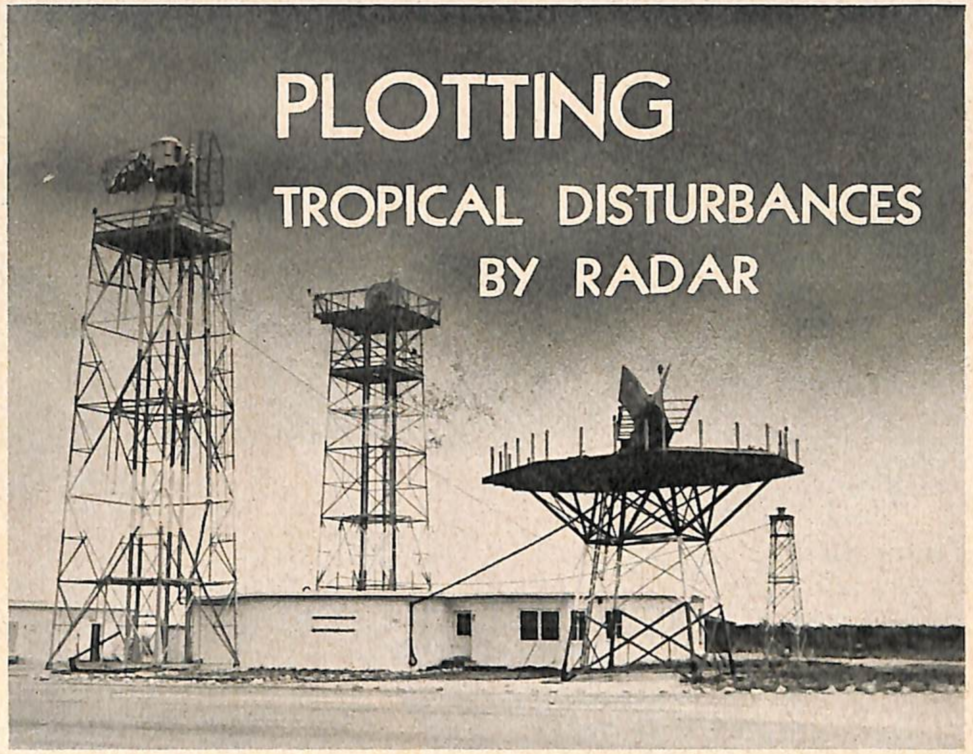
# PLOTTING TROPICAL DISTURBANCES BY RADAR



GCI-CIC AREA, Naval Air Station, Boca Chica Field, Key West, Florida.

by
Charles D. Pierce
*Office of Industrial Manager, 7ND*

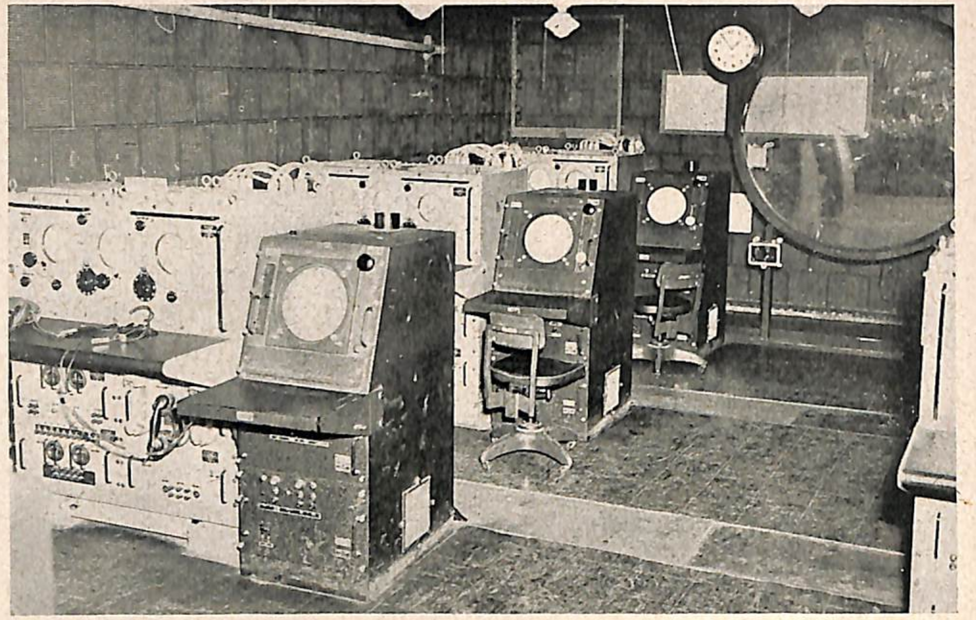
The Ground Control Intercept—Combat Information Center Facility at the Naval Air Station, Boca Chica Field, Key West, Florida, in addition to providing night flying training, has afforded an unusual opportunity for gathering information in connection with the use of radar for hurricane plotting, and observing the performance of electronic equipment under extreme weather conditions.

Boca Chica, a Spanish name meaning "small mouth," is one of the chain of islands known as "keys" stretching southwestward off the southern mainland of Florida. Boca Chica is 8 miles northeast of Key West and must be crossed in reaching Key West by highway from the mainland. The island, no point of which has an elevation of more than 5 feet, is largely marshland. It was necessary in the construction of the Naval Air Station to fill much of the area now serving as runways and taxi strips.

In April 1945, CNO approved three GCI sites for the Key West area. Cessation of hostilities made it unnecessary to complete two additional proposed sites on Matecumbe Key and at Dry Tortugas. Work at Boca Chica was begun in April 1945. There being no railroad serving Boca Chica, transportation offered some problems. All supplies were brought in by truck or ship. Temporary housing was put up immediately for the portable radar equipment, transmitters, and receivers used in preliminary and interim operation and an OCM electronic repair van was pressed into service as a maintenance facility.

The GCI station at Boca Chica commenced operation at its permanent site early in 1946. Equipment placed in the new building included a Radio Set AN/CPS–1, two Model SP–1M Radar Equipments, a Model BM and BO IFF Equipment with an AN/UPA–2 directional antenna, a Model DBF U-H-F Radio Direction

**CIC ROOM.** Three SX consoles can be seen along the bulkhead with three AN/CPS–1 Plan 12 indicators alongside. Note cable trenches in deck, also sound absorbing material on bulkhead.



Finder Equipment, and radio communications facilities (med. and v-h-f).

In May 1946, while work on the permanent GCI installation was progressing satisfactorily, Boca Chica Field was put on modified caretaker status. In the interim, until July 1946, the site was operated by units TNFTU–4 (Transportable Night Fighter Training Unit) and NightDevRonLant (Night Development Training Squadron Atlantic). In July 1946 NightDevRon moved to NAS Miami leaving the GCI site in inactive status. In October 1946 NightDevRon returned to NAS Key West, putting the radar gear back into use. During June of 1948, one Model SP–1M radar was removed and replaced with a Model SX radar.

The radar site in addition to night flying training has been used to direct lost aircraft to safety and to plot the path of tropical disturbances. The SP–1M and SX radars very clearly define the runways on the field so that CCA (carrier-controlled-approach) is possible in the event of a low ceiling.

## Plotting Hurricanes

The Models AN/CPS–1 and SX have both been used successfully to plot hurricanes. The hurricane of October 1947 was plotted very accurately and photographs of the scopes taken which proved the value of plotting storms with radar. The September and October storms of 1948 were plotted with the Model SX. The SX having greater power output and having its antenna located higher (60 ft) than the AN/CPS–1 (25 ft) presented a far better scope pattern from which to plot the photographs. The September storm last year passed directly over Boca Chica Field. An anemometer placed in the SX tower registered a sustained wind velocity of 140 mph before it blew away, and it was estimated that the instrument was 20 mph slow due to the tower structure deflecting the wind. The doors covering the transmitter and modulator for the AN/CPS–1 located on the antenna pedestal were blown off during this storm. The entire structure was filled with salt water. The only damage observed to the SX was the semi-plastic covering on the height horn. The color of this material normally is quite dark, but after the storm it was very light in color because the plastic had been removed from the weave in the covering material, leaving only the spun glass! Trouble had been experienced earlier with water entering the vent port in the very top of the SX antenna dome. This was corrected by placing a water shield under the vent with a suitable drain. The shield proved to be effective during the hurricane since no water was found in the transmitter compartment after the storm. The radar site had to be secured about an hour after the storm center had passed because of the rising tide. Sea water was beginning to enter the 15-hp motor on the air conditioning equipment as well as the alternator on the 60-kva Diesel electric equipment and wiring trenches in the GCI building.

## The Hurricane of September 1948

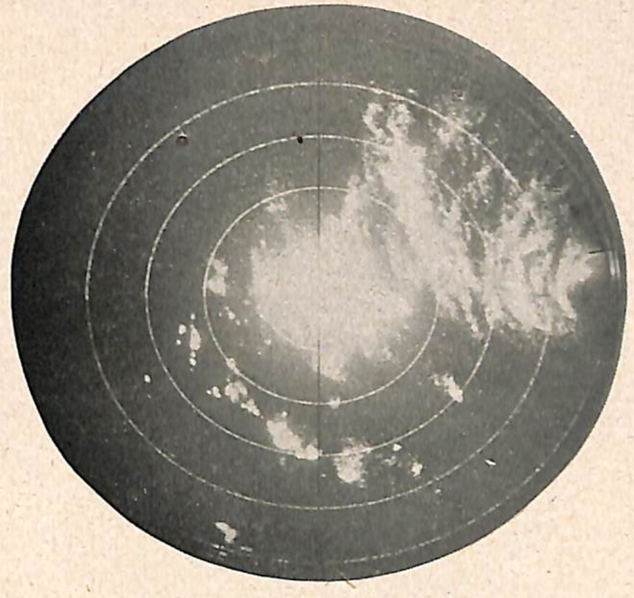
On 21 September 1948, a severe hurricane passed over the Key West area with the dead center of the storm passing about five miles to the eastward of Boca Chica Field, Key West, Florida. This storm generated winds with a sustained velocity of approximately 120 miles per hour for a period of over two hours, with reported gusts of 165 miles per hour before the wind recording instruments were carried away.

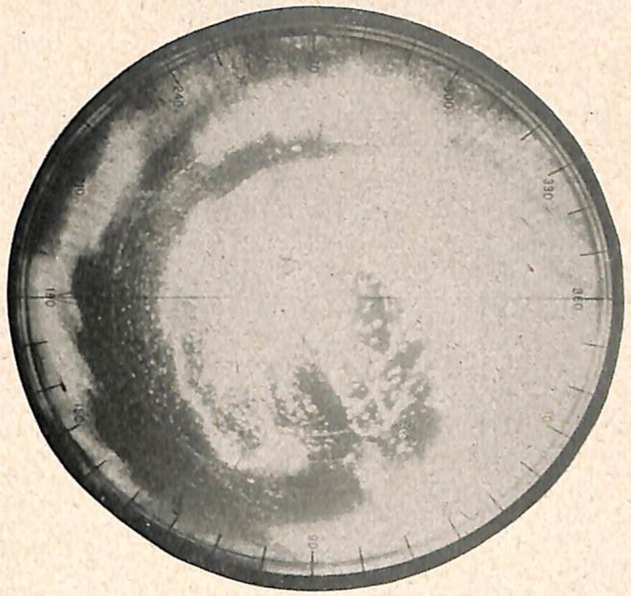
Hurricane Advisory Number One, received from the Naval Hurricane Weather Central, Miami, Florida, at 1541R on 18 September, placed the storm south of Cuba near Grand Cayman Island. This first advisory of a tropical storm stated that it was moving west-northwest at approximately 8 knots, with winds near 60 knots in a small area near the center.

Advisory Number Eight, received at 1054R, on 20 September, located the storm approximately 80 miles south of Havana, Cuba, with a course change to the north-northeast at 7 knots, and winds near the center reported at 100 knots.

All during the day of 20 September, winds were rising gradually in the Key West area and by nightfall had attained a velocity of approximately 50 knots. In view of the possibility that the storm might reach Key West area during the night, Commander, Naval Base, Key West, Florida, set Hurricane Condition One at 2000R.

At 2100R on the evening of 20 September, the ground control intercept radar site at Boca Chica Field, under the command of the Fleet All Weather Training Unit (Atlantic), made radar contact with the storm as it left the northern coast of Cuba, 12 miles west of Mantanzas Bay. For twenty consecutive hours, the GCI site plotted the storm until it was necessary to shut down, due to rising water, at 1600R on 21 September. Radar reports were sent out hourly, numbered consecutively from one through twenty, to Commander-in-Chief Atlantic Fleet, Commandant Sixth Naval District, Hurricane Weather





**TOP PHOTO,** taken 20 September, 1948 at 2108R, with scope on a 100-mile range. Eye of the storm ("eye" is the calm area in the center of a hurricane) is bearing 180 degrees at 92 wind velocity, course due north. This was the first picture made and the forward speed of the storm was determined two hours later at 4 knots per hour. The eye is just moving out to sea from the coast of Cuba 12 miles west of Mantanzas Bay and, as can be seen, the storm was badly distorted after having passed over Cuba but due to its slow forward movement over water it was well organized again after passing over the Naval Air Station.

**CENTER PHOTO,** taken 21 September, 1948 at 1149R, with scope on a 20-mile range. The eye of the storm had passed Boca Chica and winds were starting again in the reverse direction (W-NW). Until this time the storm had traveled a northerly course and the changed direction to N-NE can be seen in the photo of the filter board on the next page. The storm center at 1200, 21 September was bearing 60 degrees true at a distance of eight miles, traveling 6 knots per hour. The eye was approximately twenty miles in diameter and forty-five minutes were required for it to pass over the Naval Air Station.

**BOTTOM PHOTO,** taken 21 September, 1948 at 1610R, with scope on a 100-mile scale. The storm is traveling N-NE at about 6 knots and centered about 4 miles from Boca Chica. The echo in the eye's center is believed to be an aircraft sent out to determine the storm location. It appears unusually large because several sweeps of the scope were required to make the picture.

FILTER BOARD.

Central Miami, Commander Seventh Coast Guard District, and all ships at sea.

Below are given the hourly radar reports as plotted at the GCI site. All bearings and distances are from Boca Chica Field.

| Report No. | Time | Bearing (T) | Distance | Course | Speed |
|---|---|---|---|---|---|
| 1. | 2100R 20Sept. | 180 | 92 miles | North | ... |
| 2. | 2200R 20Sept. | 180 | 86 miles | North | ... |
| 3. | 2300R 20Sept. | 180 | 82 miles | North | 4 knots |
| 4. | 2400R 20Sept. | 180 | 78 miles | North | 4 knots |
| 5. | 0100R 21Sept. | 185 | 74 miles | North | 4 knots |
| 6. | 0200R 21Sept. | 180 | 70 miles | North | 4 knots |
| 7. | 0300R 21Sept. | 180 | 66 miles | North | 4 knots |
| 8. | 0400R 21Sept. | 190 | 60 miles | North | 6 knots |
| 9. | 0500R 21Sept. | 190 | 54 miles | North | 6 knots |
| 10. | 0600R 21Sept. | 185 | 48 miles | North | 6 knots |
| 11. | 0700R 21Sept. | 180 | 42 miles | North | 6 knots |
| 12. | 0800R 21Sept. | 180 | 36 miles | North | 6 knots |
| 13. | 0900R 21Sept. | 180 | 26 miles | North | 10 knots |
| 14. | 1000R 21Sept. | 170 | 16 miles | North | 10 knots |
| 15. | 1100R 21Sept. | 165 | 10 miles | North | 6 knots |
| 16. | 1200R 21Sept. | 160 | 8 miles | NNE | 6 knots |
| 17. | 1300R 21Sept. | 045 | 14 miles | NNE | 6 knots |
| 18. | 1400R 21Sept. | 035 | 24 miles | NNE | 10 knots |
| 19. | 1500R 21Sept. | 020 | 34 miles | NNE | 12 knots |

A study of the radar plots will indicate that the storm advanced almost due north at a slow rate after it passed the northern coast of Cuba. By daylight of 21 September, the winds had reached a velocity of approximately 60 knots at Boca Chica Field. By 1000R, the winds had reached a velocity of 120 miles per hour with gusts reported to 160 miles per hour. The winds were accompanied by a driving rain which cut visibility to practically zero.

No further advisories had been received in Key West since Hurricane Advisory Number 12 at 0254R on 21 September until after the storm had passed, and the only information available was that provided by the GCI site. The actual time that the eye of the storm reached Boca Chica was 1115R. The eye of the hurricane took about 45 minutes to pass over the field. The lowest barometer pressure reported as the eye crossed Boca Chica was 28.73 inches of mercury. At 1200R, the GCI site reported the storm bearing 060 degrees true, distance 8 miles, moving north-northeast. The wind had commenced to shift around to the northwest and west and the barometer had begun to rise rapidly. During the actual time that the eye passed over Boca Chica Field, the wind velocity dropped to practically a dead calm, and the intense driving rain that had been experienced only a few minutes before ceased completely.

### Equipment Performance

The hurricane information from the AN/CPS–1 radar was very poor compared to that obtained from the Model SX radar, and the AN/CPS–1 was secured before the storm neared the area. The SX radar, located on a 60-foot tower, operated continuously for approximately twenty-two hours, and was secured after the hurricane passed only because of the high water in the area seeping into the cable trenches beneath the deck of the GCI building. Salt water was beginning to cover some of the control cables to the radar. However, there was no damage to the SX as a result of the hurricane, and the radar returns were not affected at any time during or after the storm. With the intense driving rain, no water entered any part of the antenna assembly. The covering on the height horn was discolored for about one week, but no water entered the horn, and the cover did not lose its waterproofing effect. No height information of the hurricane was available, since the height system was inoperative before the storm and could not be repaired in time.

Although there were extremely high winds as stated before, the antenna rotated throughout the hurricane. However, at the height of the storm the antenna was slowed from four revolutions per minute to two revolutions per minute. When the wind was at its greatest force, the amplidyne showed signs of overheating, but to prevent damage to this unit additional blowers were used for ventilation.

The emergency hurricane radio net was manned at the setting of Hurricane Condition Two. This is a network of medium-frequency receivers and transmitters strategically located throughout the Key West area. The GCI site is equipped with a TCS receiver and transmitter for this purpose. At the height of the storm, this was the only means of communication, as both telephone and MC systems were knocked out.

Personnel at the GCI site during the hurricane consisted of two CIC officers, a crew of eight operators, two photographers, and a mantenance crew of five—three technicians, and two motor machinists to maintain the two Diesel generators which supplied necessary electrical power for the site.

# SPECIAL PROCESSES

## DEVELOPED BY THE ELECTRONICS SHOP

*by*
C. Allen Ducker
*Shop 67, Charleston Naval Shipyard*

The Electronics Shop was established in the Charleston Naval Shipyard on 1 March 1948. Forty-one men and three supervisors were transferred from the Electric Shop as a starting force. The shop force, which is made up of radio mechanics, electricians, apprentices and helpers, has more than tripled in its first year and has about outgrown its original home in Building 1178 which it occupies jointly with the engineers of the Electronics Ship Section.

The shop has inaugurated its first course in basic electronics, consisting of approximately 150 hours of night classes. These classes, in conjunction with training films, are being held twice weekly, and on completion of the basic course, advanced courses in radio, radar, and sonar will be given.

The Electronics Shop has developed several interesting processes and its mechanics have been the recipients of many awards for beneficial suggestions. The procedure for installing equipments on a ship's mast, which resulted from an approved beneficial suggestion, produced a $60,000 saving during the first year of its use.

The accompanying photographs show the mast, after the equipment and wiring have been installed, being lifted from the dock and hoisted to the vertical position. It is then guided to its position on the deck and lowered into place. You will notice from the close-up view of the mast being set into place that the workmen have placed small coins under the base of the mast. This is a good luck omen which has carried over from the old days of shipbuilding.

Another process developed by the Electronics Shop is the system of handling and repairing radar antennas for preservation. The following check-list and the accompanying photographs tell the story:

### Unshipping

1—Mark forward side of antenna by center punching base.

2—Disconnect and identify each lead.

3—Tape leads individually so as not to interfere with further test of equipment while antenna is off. Wrap entire cable end securely to keep out rain and moisture.

4—Electronics Shop personnel disconnect coaxial cable or rigid coaxial cable and properly seal ends. In the case of waveguide connections, coppersmiths uncouple waveguide and blank off ends properly to keep out moisture.

5—Machinists unbolt pedestal.

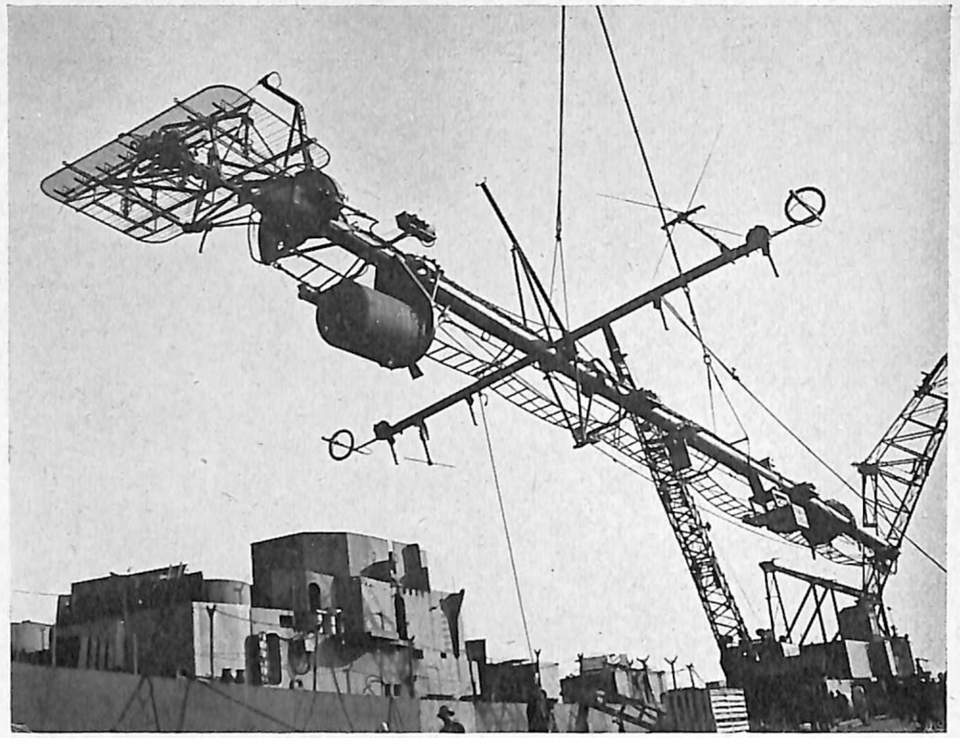
Note: When reinstalling antenna, renew hold down bolts and dip them in red lead before installing.

6—Riggers lift antenna from mast to truck.

7—Antenna is *bolted* to truck and delivered to the electronics shop for repairs.

Note: Electronics shop truck has been drilled and tapped, angle welded underneath. This has been incorporated in an approved beneficial suggestion. It saves extra manpower in handling antenna from ship to shop; hauling for sandblasting; return to ship; additional handling which might cause liquid envelope to split or tear loose.

8—After antenna has been unshipped, thoroughly clean, scrape, and paint the mast plate foundation or platform plate foundation.



COMPLETED MAST being hoisted from the dock.

9—Drill ½″ hole in foundation for drainage (if required).

## Shop Repairs

1—Check frame for leaks, and drani if required.

2—Check all eads to ground with a "megger", and renew if necessary.

NOTE: Readings to be recorded on a tag and tag to be placed inside pedestal for return to ship.

3—Check motors for continuity.

4—Bearings and gears to be checked for renewal if necessary.

NOTE: Renew bearings and gears after sandblasting.

5—Water seal truck light cable when on antenna.

NOTE: This has been incorporated in an approved beneficial suggestion.

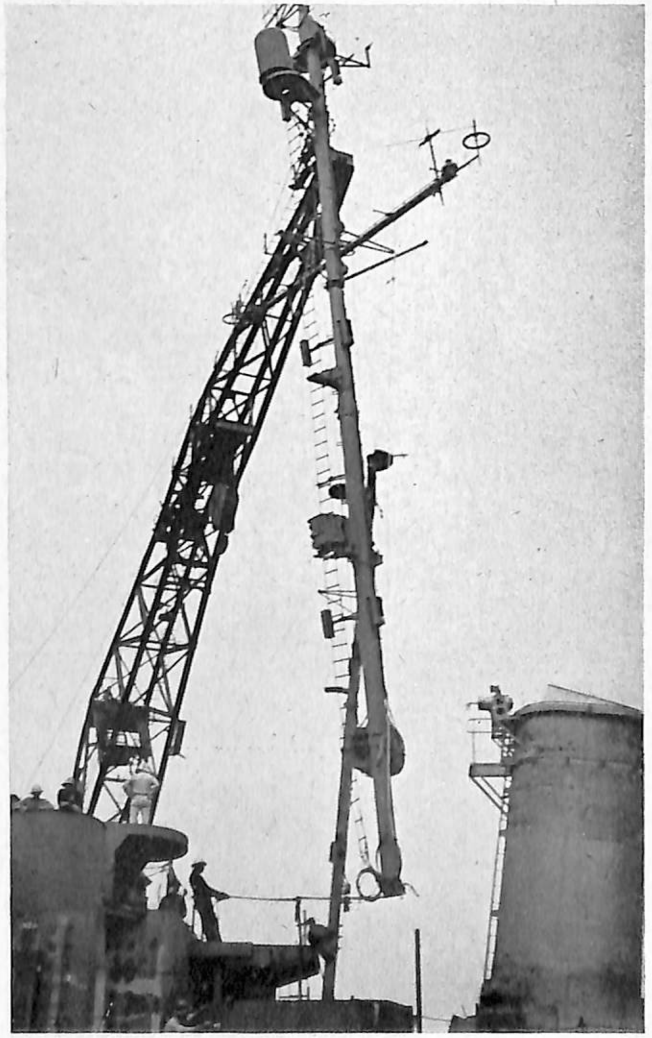
6—Check all gaskets and renew if necessary.

7—Prepare antenna for sandblasting.

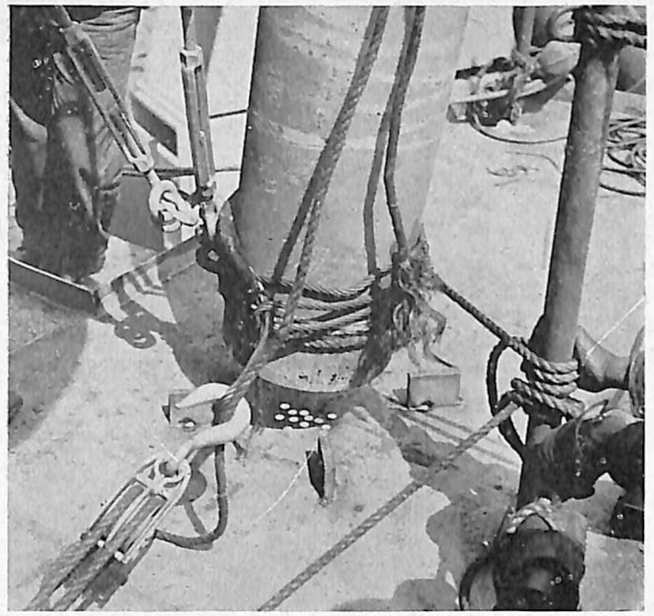
- a—Tape all insulators with cloth tape.
- b—Pack Fenox around rotating sections to keep sand out of bearings.
- c—Tape over color markings on dipole and/or bazookas.
- d—Cover bottom of pedestal with template.
- e—Stamp metal tag and secure to antenna for identification.

8—Send antenna to sandblast pit to be blasted down to raw metal.

NOTE: Do not sandblast antenna pedestal.



MAST BEING LOWERED to deck of the ship.



BASE OF MAST being fitted to the deck. Note coins placed under the mast for good luck.

9—When antenna is returned to shop from sandblast pit, spray at once with linseed oil.

10—Check and replace cracked or broken insulators.

11—Check and renew bad dipoles and bazookas.

12—Perform all field changes to bring antenna up-to-date.

13—Check frame for small holes and cracks which show up after sandblasting and weld same.

14—Test antenna plumbing for leaks under proper pressure.

15—Flush oil and change; thoroughly grease.

16—Rotate antenna for two to four hours.

17—Check selsyns for proper operation while running, through use of test panels.

NOTE: This test panel was designed and built by an electronics mechanic and is under investigation as a beneficial suggestion.

18—Drill pedestal (when required, to allow for drainage).

19—Tape all insulators before painting.

20—Painting:

- a—Two coats of zinc chromate.
- b—Two coats of aluminum paint.
- c—Remove all tape from insulators.
- d—Lock antenna in place with clamp designed for same so that antenna is facing forward.

  NOTE: Clamp for locking antenna has been incorporated in an approved beneficial suggestion. When equipment is to be operated after reinstallation, clamp is not installed.
- e—Apply two coats of liquid envelope; first coat tinted, second coat plain.

21—Provide new canvas gasket for pedestal base.

## Reinstallation Aboard Ship

1—Bolt antenna to truck for delivery to ship.

2—Riggers lift and reset on ship being careful to avoid damage to liquid envelope.

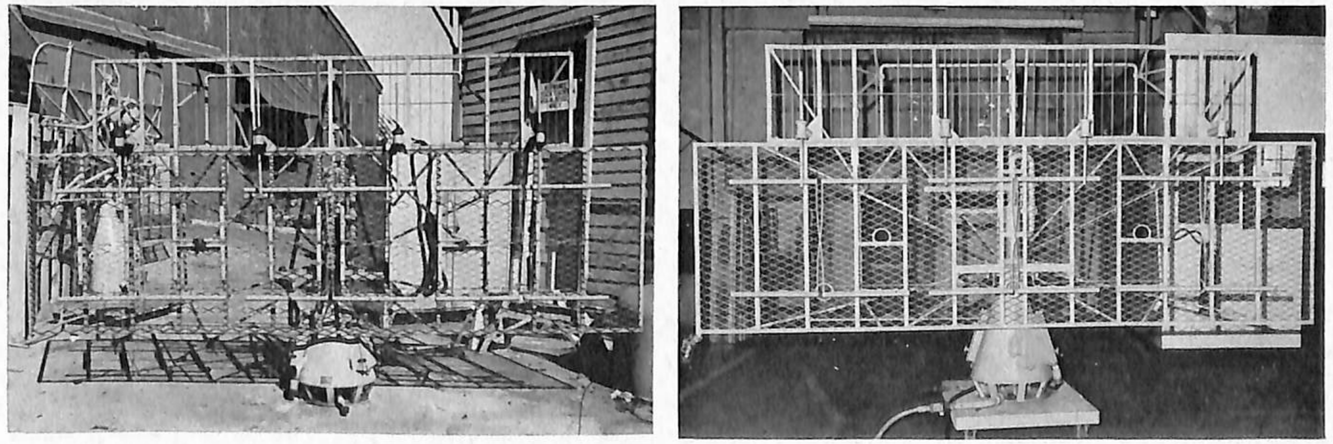
3—Machinists, using new bolts dipped in red lead, bolt down antenna.

4—Coppersmiths connect waveguide, if necessary.

5—Electronics mechanics reconnect coaxial cable or rigid coaxial cable. Slice liquid envelope around inspection plate and open same. Reconnect leads taking great care to make correct connections.

6—Place silica gel bags inside pedestal if no holes have been provided for drainage.

7—Close inspection plate and properly secure, reseal liquid envelope, and touch up any other parts of antenna as needed.



AT LEFT, an SC antenna before start of repairs. AT RIGHT, the same antenna completely repaired, repainted and ready for operational and r-f check. Note the dolly to which the antenna is bolted for handling in shop.

# OPERATION OF THE ELECTRONICS SHIP SECTION

## at CHARLESTON NAVAL SHIPYARD

*by*

JOHN R. SCHLEPPEGRELL
*Charleston Naval Shipyard*

This article describes the performance of the Electronics Ship Section of the Electronics Office at the Charleston Naval Shipyard. Inasmuch as the delineation of the functions of this Section within the over-all structure of the Shipyard has reached a point where it can be defined, it is believed that the material contained herein will be of assistance to the fleet in its contacts with the Shipyard, and also to other shipyards for comparison purposes.

Upon the arrival of a vessel, we assign engineers to assist the commanding officer in making a thorough arrival inspection of the vessel's electronic equipment. During this inspection, we make it a point to discuss the functioning of the equipment under inspection with the operating personnel aboard, seeking to connect any troubles reported by the personnel with the probable cause. We have found it of paramount importance to make the inspection as soon as possible after the arrival of the vessel for the following reasons: first, we are able to catch the operating personnel before they leave the vessel; second, the ship is still operating under its own power; third, it allows time for the preparation and submittal of the report of the arrival inspection to the commanding officer prior to the convening of the "arrival conference". The commanding officer usually uses our inspection report as a basis for submitting a request to the type commander for approval of additional electronic repair items to be accomplished during the ship's availability. The forwarding of the inspection report completes the first phase of our job.

The engineers assigned to a ship (usually one each from the radio, radar, and sonar units) are responsible for the technical phases of the work performed by the various shops during the availability of the vessel. This responsibility is discharged by continuing inspections while the work is in progress. It also involves the review of plans prepared in the design branch of the Planning Department.

As the work aboard ship continues, the advice of the Ship Section of the Electronics Office on the technical aspects of the electronic work is made available to both the Production and Planning Departments in the discharge of their portions of the work.

Many of the equipments repaired in the shop require a so-called "bench-test" or "shop-test" prior to return to the vessel. Such tests are usually observed by engineers from the appropriate unit of the Ship Section, and the test sheet resulting from this test is signed by the engineer. This completes the second phase of the job.

The third and final operation of the Ship Section consists of a thorough final test at the completion of the scheduled work near the end of the availability. The purpose of this test, which is conducted in the presence of the cognizant ship's officer, is to insure that the vessel is in all respects "ready for sea", as far as electronics is concerned. Any defects noted are promptly brought to the attention of the shop concerned and emergency steps (which are usually necessary at this stage of the game) are taken to correct the faults.

When it has been demonstrated that the equipment is performing satisfactorily, the approval and acceptance of the equipment by the ship's representative and the approval of the final operation by the engineers from the Ship Section are indicated on an approval form commonly known as "the green tag". The approval form is about the size of the ordinary shipping tag and it is perforated in the center. The engineer signs the top half of the tag and hangs it on the equipment, and both the engineer and the ship's officer sign the bottom half of the tag which is retained by the engineer and filed in the folder for the vessel in the Ship Section files.

In the process of performing this work, we have found that it is possible to generate a fairly complete set of records on each vessel which are particularly useful in forwarding information to the vessel concerning the equipment which was serviced during the shipyard availability. Such material is invaluable to the maintenance personnel of the vessel for completing and maintaining logs on the work accomplished at the yard, and, also, to be used as a guide in tracing further trouble in the equipment. We forward this information to the vessel by letter, with as much detail as we can include, as soon after the completion of the work as possible.

# YOUR EQUIPMENT RECORDS

*by*

RAYMOND ROSEMAN
*Charleston Naval Shipyard*

One of the most useful tools available to the electronics technician in his maintenance work is a complete and accurate set of records. The Bureau of Ships, recognizing this fact, has developed forms which are simple to fill out, and give the necessary information when properly made up.

It has become increasingly important that written records be kept for all major electronic equipments. The shortage of trained electronics personnel has made the fleet, especially the smaller vessels, more and more dependent on shipyard facilities even for some of the maintenance which is normally handled by ship personnel. A complete exchange of information between the ship's personnel and the shipyard engineer is one of the first steps towards returning the electronic equipment aboard the vessel to optimum operation.

To impart from memory an accurate word picture of the events leading up to the breakdown of a radar, sonar, or radio transmitter is extremely difficult even for a technically trained man. Then, too, the failures of six or eight months ago may have a direct relationship to your present troubles.

When an engineer comes aboard to make his arrival inspection, at the beginning of your ship's overhaul, he will, with the aid of your log, be in a better position to accurately diagnose the troubles of your equipment and thereby be better able to send you out with some "hot" gear.

It is worth remembering that when the fellow that used to take care of your electronic gear was transferred or discharged, he took with him, in his mind, all the records of your equipment troubles unless he left behind an accurate and carefully kept log.

Bear in mind that *all* information pertaining to the troubles and operation of your equipment is important. Do not try to sift the important items from those you may judge to be unimportant. A blown fuse may tell a more pertinent story than a burnt out transformer. If you will log each and everything you or someone else does to the equipment, your record will be very complete and the overall operation will be greatly improved.

The log has another very important function that cannot be overlooked. In making out your work requests, prior to an overhaul, if you will consult your log you will be in a better position to accurately judge the condition of your equipment and have a knowledge of which field changes should be made to put it in peak operating efficiency. It has been found that ships that do not keep records, or keep them poorly, rarely have all the field changes necessary for maximum performance, nor do they know which have been installed.

Keeping careful and accurate records for every major piece of electronic equipment is one of the first steps toward better maintenance and that happy day when you can have the pleasure of making your electronic equipment work for you instead of you working for it.

# MODEL QHB/QHBa OPERATIONAL USE

In clarification of Section 4–1, fifth paragraph, of the Model QHBa instruction book NavShips 91125, it should be noted that when target doppler nullifier switch S–701 on the receiver-converter chassis of the sonar receiver-transmitter is in the ON position, target doppler nullification is obtained *only* when audio switch S–101 is in the PEAK position. It is highly desirable, therefore, that S–701 be left in the ON position so that target doppler nullification is obtained when S–101 is switched to PEAK. In the BAND position of S–101 no doppler effect is lost, as the TDN circuit is automatically disabled.

**BOX SCORE** **BuShips Electronics Repair Parts Program**

| Allowances | Type Vessels | Percentage Completed |
|---|---|---|
| ELECTRON TUBES | Submarines | 100% |
| | Surface | 91% |
| REPAIR PARTS | Submarines | 43% |
| | Surface | 0.2% |

# INTERFERENCE REDUCTION

*by*

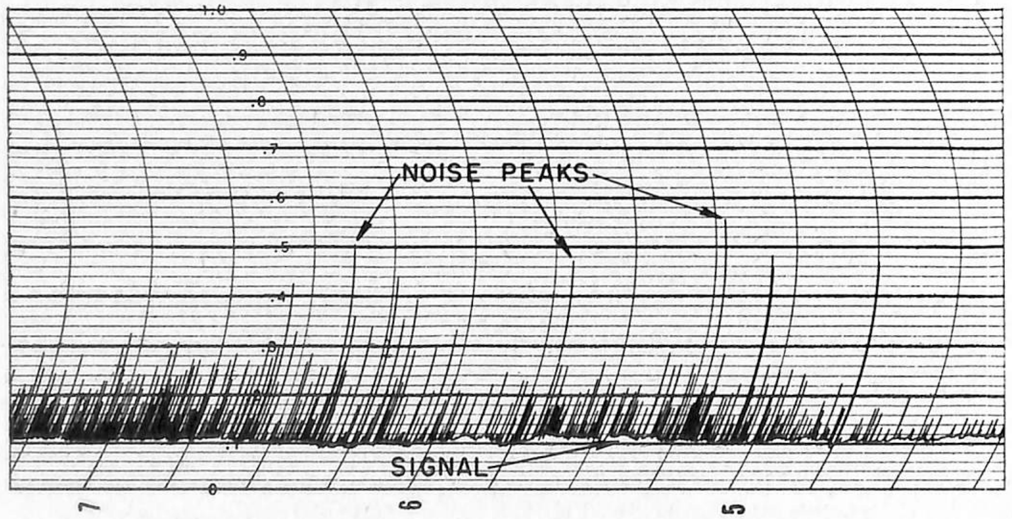
LEONARD W. THOMAS

*Electronics Design and Development Division,*
*Bureau of Ships*

Radio Interference is defined as any electrical disturbance which causes undesirable response or malfunctioning of communications equipment. Communications equipment is defined as all electronic devices, either systems or components thereof, used in transmission or reception of intelligence. Such equipments include radio, radar, underwater sound, television and electronic detection, recognition and relay devices, all of which employ radio-frequency energy transmitted through space or through other media for their proper functioning.

These equipments are susceptible in varying degrees to interference whether created by equipments of their own type, by other types of equipment employing electric circuitry, or by manmade or natural disturbances sometimes know as "static." Their effectiveness depends upon their ability to perform the function for which they were intended utilizing to the fullest extent those characteristics which were designed into them. Such cannot be realized in the presence of interference. A receiving equipment constructed with a sensitivity of one microvolt cannot take advantage of its ability to receive a one-microvolt signal if that signal is submerged in high levels of interference. Many such receiving equipments are constantly subjected to ambient intereference levels of from 100 to 1000 microvolts, or 40 to 60 decibels above the available sensitivity of the receiver. For satisfactory manual reception of code signals, the signal-to-interference ratio should be at least unity. This is interpreted as requiring that the received signal should equal the interference with the result that the receiver operate at a sensitivity of 100 to 1000 microvolts. A receiver of that initial sensitivity could be constructed at a fraction of the cost of a receiver with one-microvolt sensitivity.

The reduction of interference is a comparatively new art. While interference has been recognized for quite some time as being harmful to the proper functioning of electronic equipments and isolated attempts have been made to limit its effects on communications equipment, it was not until after the last war had started that any concerted and coordinated effort was made to gather together information for a concentrated attack on this enemy of communications.



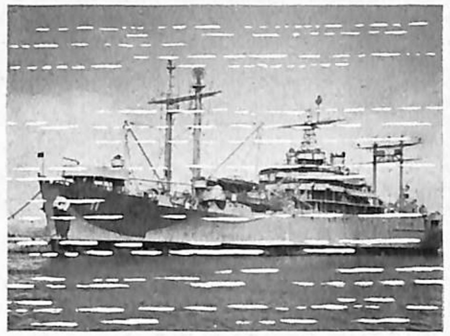
RECORDING of CW SIGNAL, showing noise peaks interposed.

Early in 1942 the need was foreseen for such an attack, and it was proposed that a problem be set up under the auspices of the NDRC for a study of "radio interference" (sometimes termed "radio noise," or just "noise") and its effect on communications. This study was recommended to include methods of measurement and means for the reduction of interference to acceptable levels. This program was sponsored by the armed services and they, having the most urgent requirements for the reduction of interference, expended large sums of money in basic and applied research on this subject. Certain of these programs have been continued without interruption since their initiation, and they have continued to supply the services, civilian industry and various international organizations with basic information concerning interference, its parameters and its effects on communications of various forms. One of these programs is that with the University of Pennsylvania where, under the very able direction of Dr. Carl C. Chambers, this program has made outstanding progress and has been recognized all over the world for its findings and contributions to the measurement and reduction of interference.

Until recently specifications for the reduction of interference have been defined in terms of decibels between the value of interference noted prior to reduction measures, and that value of interference noted after the application of reduction measures. Existing interference measuring equipments have been utilized to obtain these values, and they were operated under closely prescribed conditions. At the present time the unit of measurement of interference amplitude is the volt. As the full value of a volt or volts of interference has been encountered in few instances, it has been convenient to express measurement values in whole numbers, so the term "microvolt," one-millionth of a volt, is used. In general, the services by specifications are requiring the reduction of interference over a comparatively wide range of frequencies. Certain existing specifications require the reduction of interference from 15 kilocycles to 400 megacycles. Other specifications require the reduction of interference from 150 kilocycles to 1000 megacycles, and others up to and including 4000 megacycles.

In order that interference may be measured with some degree of accuracy and repeatability, there is need for the establishment of a standard group of measuring instruments. These equipments would be amenable to use by laboratory and field personnel with some assurance of obtaining readings or indications of interference that can be duplicated within the limits of accuracy of standard laboratory measuring equipment.

At the beginning of the last war, only two measuring equipments were available that could be utilized for the measurement and reduction of interference in the medium-frequency range. These equipments were manufactured in accordance with the joint recommendations of industry in 1940 that specified a standard instrument for the measurement of interference. An additional instrument was also available for the measurement of interference at higher frequencies. These three equipments were used extensively during the war for the measurement of interference by both the services and industry. Their production was controlled by the War Production Board and allocations made in accordance with justified requirements for them. Needless to say, no one ever secured a sufficient quantity of these instruments to satisfy even minimum requirements. Nevertheless, these instruments performed admirably in the face of many difficult situations.



**RADIOPHOTO TRANSMISSION, showing noise bursts caused by radio interference.**

The upper limit of these instruments was 150 megacycles, and the assignment of certain military communications to the ultra-high frequency band rendered them useless over this new range. Interference was known to be present over this new range. This fact had been substantiated by attempted operation of the developmental communications equipment, but there was available no interference measuring equipment with which to evaluate such interference in terms of the microvolt. To fulfill such a requirement the services contracted for the development of an interference measuring equipment whose frequency range extended to 400 megacycles. A limited number of these equipments were procured, and they were effectively used over this new band.

Realizing the shortcomings of interference measuring equipments within the presently covered ranges, the Signal Corps Engineering Laboratories developed Radio Test Set AN/URM–3. This equipment incorporated a new method of measurement, commonly known as the "slideback voltage" method. The AN/URM–3 was designed primarily for use in the reduction of interference in vehicles and items using internal combustion engines. The principles of measurement embodied in this equipment were examined very closely by other branches of the service. In order to take full advantage of this method, this feature was included in the design of new interference measuring equipments subsequently undertaken by the Navy. Also, certain existing interference measuring equipments were modified to include this method of measurement.

The development of new circuits, new electron tubes and new types of communication over greater frequency ranges made mandatory the measurement of interference over these frequencies. Specifications were written covering Radio Interference and Field Intensity Meters over the range 14 kilocycles to 1000 megacycles. Development contracts were awarded for the construction of equipments covering this range. Two of these developments have now been completed, and the production of equipments within the range 14 to 250 kilocycles and 150 kilocycles to 25 megacycles has started. The equipment covering the first range is known as the AN/URM–6, and the second equipment covering the latter range is known as the AN/PRM–1. Upon their availability, production models of these equipments will be examined in the laboratories of the services where they will be considered for adoption as inter-service standards for the measurement of interference. It is anticipated that commercial measuring equipments, measuring in terms of these standard instruments, will be available to industry. The continuing utilization of the frequency spectrum below 14 kilocycles and above 1000 megacycles makes it necessary to consider the design and development of interference measuring equipments beyond these limits. Specifications are presently being written for such equipments, and it is anticipated that developmental contracts will be awarded for their construction.

Investigations into methods of interference measurement using existing equipments have been made by the University of Pennsylvania. Results indicate that the measurement of interference should include more than just the value of its amplitude. While interference measurements, to give meaningful results, are not possible with all existing equipments, those newly developed Radio Interference and Field Intensity Meters will include such quantities. These quantities are:

1—The average value of interference.

2—The quasi-peak or weighted detector value of interference utilizing a detector weighting circuit of one-millisecond charge and 600-millisecond discharge.

3—The peak value of interference utilizing the "slide-back voltage" method of measurement. This peak value is obtained by biasing the second detector by the application of a d–c voltage to that point where the measured interference observed by aural monitoring vanishes. The indicating meter indicates the value of this d–c voltage which is also the voltage of the measured interference. (This value is more nearly representative of the nuisance value of impulsive interference to television and other visual indicating and "relay operating" electronic equipments).

4—If of the impulsive type, the repetition rate of the interference.

5—If of random type, a description of the aural response of the measuring equipment.

6—The bandwidth of the measuring instrument.

7—The overload characteristics of the measuring instrument.

TELEVISION RECEPTION, showing distortion and disruption caused by radio interference.

There are many types of interference, and these various types are produced by many different items, both electrical and mechanical. The compilation of a list of probable interference sources would be a never-ending task. Each specific type of interference possesses its own characteristics. For instance, the interference produced by the ignition system of an internal combustion engine is present over a wide frequency range. Its nuisance value is negligible in the very-low and low-frequency bands. In the medium- and high-frequency bands its deteriorating effects on communications are serious, but the application of simple resistor-suppressors in the high-tension leads and capacitors on the battery input lead of the engine usually reduces the interference to low values. In the very-high and ultra-high frequency bands the untreated ignition system is a prolific source of interference. Complete shielding of the entire ignition system together with filtering all battery leads at their point of entry into the shield is usually required to reduce this interference to acceptable levels. An interference reduction of approximately 100 decibels, a ratio of one-hundred-thousand to one has been realized in some ignition systems.

After the determination of the characteristics of a specified interference, the susceptiveness of various electronic systems should be ascertained in order that the deteriorating effects of this interference on them might be known.

Television, for example, is more susceptible to impulsive interference than is a frequency-modulated speech communications system.

A radio man can receive code from a keyed-carrier, ICW modulated transmitter in the presence of a greater background of interference than can a radio-teletype system.

The bandwidth of a receiver is also a factor governing the amount of "random" interference that is present as the "background" of the received signal.

Long-range point-to-point communications systems operating in the very-low-frequency band are not subject, as a rule, to interference from ignition systems. They are, however, greatly interfered with by interference from high-power direct-current motors and generators.

A television picture will show evidence of interference even though the intensity of the interference is only one one-hundredth of the intensity of the received television signal. A direct-current machine, even if located close to the television receiver, will cause very little if any interference to the television picture.

Interference from fluorescent lamps is particularly intense in the lower-frequency ranges, but with increase in frequency gradually becomes less. The application of a simple "pi"-network filter in the power leads to such lamps will reduce fluorescent lamp interference on power lines leading from these lamps to tolerable levels. One problem remains, however, that of reducing the direct radiation from the fluorescent tube outward into space. Considerable progress has been made in solving this problem by the use of a conducting glass over the light opening of the fixture. The body of the fixture must be of closed metal construction with all ventilation openings screened, and the conducting glass must be fitted with a continuous metallic contact area around its periphery to which the metal fixture must make continuous contact. Fluorescent fixtures containing two fifteen-watt tubes have been rendered interference-free in this manner. The frequency spectrum from 150 kilocycles to 400 megacycles was searched for evidence of interference from this fixture. It is interesting to mention here that the particular conducting glass used in these tests imparted no color-characteristics to the light from the fluorescent tubes, and light-transmitting efficiency of the glass over plate glass of the same thickness was about 3% less.

One group of engineers engaged in interference reduction work recently encountered diametrically opposite interference conditions in one equipment. A sound-on-film motion picture projector was a severe source of interference to communications in the medium- and high-frequency bands. Two ac/dc universal type motors within the projector produced this interference. At the same time it was reported that the sound system of the projector was picking up energy from a nearby radar system whenever the radar beam "swept" the projector. Investigation into the latter interference condition revealed no "interference" from the radar other than its intended untra-high frequency output on its assigned frequency. The projector was then examined, and it was found that the shielding around the photo-electric cell, around the cell leads to the amplifier, and grid leads of two amplifier tubes was inadequate. The steep wave front characteristic of the radar beam had apparently shock-excited the high sensitivity audio leads between the photo-electric cell and the amplifier of the projector with the result that its audio system exhibited pulse repetition rate characteristics of the radar system.

In conclusion, may I make a few observations on the field of interference reduction and on the people engaged in this work:

It is my belief that no other field of endeavor within electronics offers so great an opportunity to be of service to man.

It is far more economical to reduce interference than it is to increase transmitter power.

Accomplishments to date in this field are only a small part of the overall problem. Many major obstacles remain.

Many manufacturers producing devices that previously have been sources of interference are now voluntarily incorporating interference reduction measures into their products. Among them are the manufacturers of automobiles, electric appliances, office machines and many others.

The American Standards Association Committee C63 on Radio-Electrical Coordination has been actively engaged in this field for many years. Their work has brought together the manufacturer, the scientist and the services, so that many otherwise difficult interference problems have been resolved.

Through the facilities of the American Standards Association contact is maintained with the Special Committee of Experts on Radioelectric Interference of the International Electrotechnical Commission. Much valuable technical information concerning interference has been exchanged between the ASA and the IEC.

# CHECKING U-H-F SYSTEMS

by

*Commander Battleships-Cruisers, U. S. Atlantic Fleet*

It has been demonstrated repeatedly that u-h-f communication is satisfactory—and, in fact, at least equal to what has been experienced with Model TBS equipment. It is unique, however, in requiring that all the parts of the system operate normally in order to avoid communication failures. To that end, it is desirable to have at hand some means of checking the parts of the system, and the over-all performance.

A simple check with a nearby ship, and a report of "I hear you loud and clear," indicates little more than that the equipment is turned on, patched to the right outlets, and on the same channel. It does not indicate whether a slightly greater range is obtainable. This indication, however, can be obtained from the equipment with little additional work.

Although there have been many statements made to the contrary, it is still true that adequate range is obtainable only by reducing the losses (expressed in *decibels*) over the complete circuit to a satisfactorily low level. Assuming some signal-to-noise ratio at the headphones as being necessary for satisfactory reception, it is possible to figure the transmitter power necessary if the receiver sensitivity, cable loss, receiving antenna gain, attenuation in space, transmitting antenna gain, and transmitter cable loss are known. It follows, therefore, that for a known distance between stations, it shoud be possible to use the input meter of a Model RDZ receiver to determine whether there are any unacceptable losses in the system. This over-all check will be discussed in greater detail following a discussion of methods of checking parts of the system.

The receiver sensitivity shoud be measured. It should be possible to obtain a 10-db signal-to-noise ratio with less than 10 microvolts input from a signal generator, such as Model LAF. This subject is discussed in the instruction book; it need not be covered in detail here.

The sensitivity of the receiver may also be measured through associated cables and connectors (including the transmitter antenna relay if the same antenna is used for transmitting and receiving) in order to aid in locating trouble in associated local cables and connectors.

With a suitable fitting for a megohmmeter (UG–21/U connector and US–29/U adapter), the antenna cables can be checked. A resistance reading well below one megohm suggests a short-circuit developing in the cable; a reading of several hundred megohms suggests that the inner conductor may be open. A more complete check of open circuits is given by shorting the insulated half of the antenna dipole to ground, but the protective paint makes this method unsatisfactory as a routine measure. Removing the antenna connector, and shorting the inner conductor of the cable to the copper braid, gives a useful check but in one case this did not disclose an open circuit within the antenna itself.

It is well to know the cable loss between the receiver and the antenna. This can be determined by disconnecting the cables from two antennas, and joining the cables with a UG–29/U connector in order to form a loop. Connect a signal generator, such as Model LAF or LX, to the receiver and adjust the attenuator to give a convenient reading, such as 0.25 ma., on the receiver's input meter. Then connect the receiver and signal generator to the two ends of the loop of cable and readjust for the same input meter reading. The difference between the two readings of the attenuator give the total cable loss, roughly half of which is in each cable. This may be checked further by measuring other combinations of r-f cables after making other connections on the mast, to determine the exact loss in each cable. The loss in an average length of RG–18/U may be as low as 6 decibels, but losses as great as 18 decibels have been found in long runs of smaller cable.

The above check gives a positive measure of cable loss, but requires making connections on the mast. A routine over-all check can be made from the receiver location with much less work. This is done by connecting the signal generator to one antenna cable, and picking up the signal in a receiver connected to another antenna. With close spacing of antennas (about 6 feet) and moderate runs of RG–18/U cable, the round-trip loss will be around 30 db. With an antenna spacing of about 60 feet, the loss will be around 50 db (20 db more for a 10-to-1 increase in antenna spacing). Either figure will be greater with longer cable runs or smaller cable. This type of check can be made regularly in a few minutes, giving an early indication of cable or antenna trouble. It is superior to using a "megger" because it shows trouble that does not give abnormal megohmmeter readings. The following two sets of measurements of the signal generator output in decibels required to give the same input meter reading at Fifth Naval District headquarters illustrate the point:

| | *21 January* | | *23 February* | | |
|---|---|---|---|---|---|
| | *attenuator* | *loss* | *attenuator* | *loss* | *change* |
| Model LAF direct | —56.0 | — | —68.2 | — | — |
| Antenna #1 to #2 (about 40 feet) | — 9.3 | 46.7 | —15.9 | 46.6 | —0.1 |
| Antenna #1 to #3 (about 40 feet) | — 9.2 | 46.8 | — 5.7 | 62.5 | 15.7 |
| Antenna #2 to #3 (about 4 feet) | —27.6 | 28.4 | —17.7 | 44.8 | 16.4 |

It will be seen from the above figures that antenna #3 developed an increased loss of about 16 db, although it continued to check satisfactory (300 megohms) on a "megger." This procedure, therefore, is very helpful when the figures have been recorded from time to time, and when the magnitude of the round-trip loss has been determined to be satisfactory.

Most transmitter tuning should be done with an ME–11/U Wattmeter substituted for the antenna. This not only eliminates interference with other ships, but enables proper tuning to assure an output of 20 watts or more from the TDZ. The antenna circuit, dials K and L, may be retuned for maximum deflection on the transmitter tuning meter, after the antenna has again been connected to the transmitter, since some standing wave conditions on the transmission line may make such retuning necessary.

The wattmeter may be moved to the antenna end of the transmitter cable to check cable loss. The wattmeter may also be connected to an adjacent (or unmounted) antenna to ascertain that the antenna itself is radiating power effectively. If the wattmeter is connected at the transmitter end of the cable leading to an adjacent antenna, the reading is likely to be less than one watt which is not adequate for a satisfactory system check but does give some confidence in the performance of the r-f cables and the antennas. If a receiver is available near the transmitter, however, the receiving antenna checking procedure described above can be used to measure the round-trip loss in two antennas and their cables.

For routine checking of the u-h-f system, it is more convenient to check both the transmitting and receiving portions of the system at the same time. This may be done by using a TDZ transmitter on its normal antenna and observing the input meter of an RDZ receiver operating from a separate antenna. Inasmuch as the signal varies as 1/d (inverse distance) within the horizon (changing to $1/d^2$ beyond), there is a direct relationship between the receiver input meter and the distance range on the surface that can be expected of the equipment. For ships with high antennas, approximately the following should be experienced:

| Input Meter (ma.) | Distance Between Antennas | db Below 0.1 v. |
|---|---|---|
| 0.87 | 6 feet | – |
| 0.82 | 60 feet | 9.0 |
| 0.74 | 600 feet | 29.0 |
| 0.60 | 1 mile | 49.0 |
| 0.36 | 10 miles | 69.0 |
| 0.05 | 20 miles | 95.0 |

The above figures have been exceeded by receivers in the *USS Missouri* (*BB–63*) and equalled by the *USS Adirondack* (*AGC–15*). Several other ships were less effective. It will be seen immediately that except for meter readings above about 0.85 ma. which are less accurate, observation of the RDZ input meter tells much more about the operation of u-h-f equipment than does the fact that "strength five" signals were received at all the distances listed above. The system described in the above paragraph is applicable to equipment on the same ship, nested ships, or widely spaced ships. Therefore, it provides a useful tool to confirm satisfactory operation of u-h-f equipment, and to assist in locating faulty equipment or installations. It provides a means of checking each channel of each transmitter against each receiver, to provide assurance that there are no inoperative channels. It does not, however, directly check the antenna radiation at all bearings though this also may be done by swinging ship and observing the input meter variations. In a normally sensitive receiver, the input meter changes close to 0.1 ma. between 0.1 and 0.5 on the scale, for each 6–db change in receiver input.

| Type of Approach | Last Month | To Date |
|---|---|---|
| Practice Landings . . . . . . . | 9,660 | 234,294 |
| Landings Under Instrument Conditions . . . . . . . . . . | 272 | 12,784 |

# LINES[1]

by

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## Introduction

Knight's Modern Seamanship (10th Edition) defines a "line" as "a general term for light rope." In the modern Navy this definition must be regarded as incomplete, for extensive use is made of transmission lines for various purposes in Navy electronics. The present paper is confined to a discussion of the relative merits of several classes of lines, including waveguides, for various military applications. Comments are restricted to electrically long lines; i.e., lines comparable to a wavelength in overall length. (The voltage and current distribution along an electrically long line may or may not be uniform, depending upon the termination.) Falling into this category, for example, are video cables employed for the interconnection of electronic equipment aboard ship, and transmission lines used for conveying the radio-frequency power output of a transmitter into a directional antenna at a shore radio station.

Some of the more important applications of transmission lines and line sections, in addition to their obvious function of transferring power from one location to another, include use as impedance transformers with low losses, high Q tank circuits in oscillators and tuning circuits in microwave receivers, filters and harmonic suppressors, as well as pulse shaping networks or rectangular wave generators. In many microwave circuits line sections are employed as insulators! Only recently a "distributed" video amplifier was built which employs transmission line sections and has a band pass width of several hundred megacycles.

In the Navy considerable use is made of the two-wire line with air dielectric, coaxial cables, and waveguides. The four-wire line with air dielectric (having the diagonal wires connected in parallel) is probably not employed as much as its excellent characteristics warrant. The two coaxial cables in general use are the gas (or air) dielectric and solid dielectric types.

The writer does not propose to describe in detail the physical appearance of any transmission line mentioned above nor make any statements concerning line constructional practice. Suffice to say that open wire lines (whether of the two- or four-wire type) are supported at intervals by insulators secured to poles. Additionally, the insulators insure that the spacing between wires is uniform. One coaxial cable type consists of a cylindrical copper tube within which is supported a solid copper wire of cylindrical shape. Small ceramic discs equally spaced along the line act as insulators and supports for the center conductor. Ordinarily such lines are dehydrated and then an inert gas, such as nitrogen, is kept in the line (under pressure) to prevent moisture from entering. Trunks, as used aboard ship, may be regarded as a form of coaxial cable. Usually trunks are not moisture-proof. The solid dielectric type of coaxial line consists basically of a woven stranded outer conducting sheath and a center conductor (either of solid or of stranded copper wire) immersed in a low-loss solid dielectric. Waveguides are relatively thin-wall copper tubes of either rectangular or circular cross-section, depending on application.

## Factors Effecting the Choice of a Line Type for a Specific Application Aboard Ship

One would be extremely naive to suppose that extensive use of open-wire lines could be made aboard ship. The vast number of electrical interconnections required between compartments of a modern Naval vessel would preclude the use of appropriately spaced open-wire lines, for not only would space limitations prevent this but it would be extremely difficult to achieve compartment integrity (from the point of view of water-tightness); the shock hazard would be ever present; switching arrangements are cumbersome; and it would be difficult if not impossible to obtain satisfactory electronic equipment operation due to coupled circuit effects existing between the maze of wires. Further, at very high frequencies (when the spacing between wires of the line becomes comparable to the wavelength) an open-wire line may be regarded as a special form of antenna array. Under such circumstances much of the power supplied to the line may be radiated, little or no power being delivered to the load. The objective of the line is thus defeated. The use of either a coaxial cable or waveguide is indicated.

The longest wavelength or dominant mode that can be transmitted by a hollow conductor of rectangular cross-section having sides a and b (inside dimensions) ($a > b$) is determined from inequalities $a > \frac{\lambda\text{TEM}}{2}$ and $b < \frac{\lambda\text{TEM}}{2}$ ($TE_{1,0}$ mode). Here $\lambda$TEM is the wavelength taken in empty space ($\lambda$TEM in meters equals $3 \times 10^8$ meters per second divided by the frequency in cycles per second). There is no lower limit for the value of b, exclusive of zero. It can be made as small as desired, but attenuation increases with decreasing values of the dimension b.

The longest wavelength or dominant mode that can be transmitted by a hollow conductor of circular cross-section having inside radius b is determined from the inequality $b > \frac{\lambda\text{TEM}}{3.41}$ ($TE_{1,1}$ mode).

Suppose it is desired to convey radio-frequency power having a frequency of 25 megacycles per second from a radio transmitter aboard ship to a topside antenna. For this case, $\lambda$TEM equals 25 meters or 82 feet. If a waveguide of rectangular cross-section is employed the dimension a will have to equal or exceed 41 feet! If a waveguide of circular cross-section is suggested for this application, its radius will have to be in excess of 24 feet! As a matter of interest, no waveguides of circular cross-section are in general use in the Navy, exclusive of their use as waveguide fittings for rotating joints, etc. No rectangular waveguides are employed aboard ship where frequencies below twelve hundred megacycles per second are involved.

From the above discussion it is clear that waveguides have no application at communication frequencies. Accordingly, the use of a coaxial cable is indicated. The question is whether the gas-filled line or the solid dielectric cable should be employed. Unfortunately, the solid dielectric coaxial cable has higher inherent loss (attenuation) than the gas-filled line. But the gas-filled line suffers from the disadvantage that it must be maintained gas tight. This is not easy to accomplish on a flexing ship. If all lines used aboard ship for electronics applications were gas-filled, rupture of the lines in battle would certainly be a personnel hazard.

It appears, therefore, that in spite of its high losses the solid dielectric coaxial cable is the optimum line for shipboard applications (exclusive of high tension applications, involving long and medium wave transmitters, when trunks are necessary) provided the frequencies involved are not too high. Such a line is of little or no use in microwave applications, as it is entirely possible for a relatively short line to absorb the entire power output of a transmitter, thus delivering no power to the antenna. Research is being conducted toward the development of a dielectric material which is not only low-loss, but impervious to moisture. It is worth mentioning that the absorption of moisture by the line is accompanied by severe attenuation of the signal.

The solid dielectric cable is easy to "pull" into position aboard ship and requires essentially no maintenance provided the cable terminations (or fittings) are properly installed by shipyard mechanics. Considerable forethought must be exercised in preparing installation drawings for such cables, as many electrical failures are directly attributable to the cables' proximity to hot stacks, fire rooms, etc. It is hoped that future development will evolve a good low-loss, moisture-impervious, high-temperature-resistant cable for general shipboard use.

Rectangular waveguides are used exclusively for long hauls where microwave frequencies are involved. Happily, the loss of power in the guide is small if it is properly designed and installed.

**FIGURE 1** Transmission line asymmetrically arranged with respect to the input terminals of a symmetrical center-driven antenna.

## Factors Effecting the Choice of a Line Type for a Specific Application Ashore

Open wire transmission lines have a very important application at shore radio stations.

The two-wire line is well adapted for connecting high power transmitters (operating at communication frequencies) to balanced antennas, such as rhombics installed on open territory. (By definition an antenna is balanced if it is symmetrical with respect to its input terminals from the point of view of the geometrical arrangement of the conductors forming the two halves of the radiating system, and with respect to nearby objects, such as the earth.)

The fact that two-wire lines are generally satisfactory for use at transmitting stations ashore (except where climatic conditions preclude their use) is not prima-facia evidence that such lines are useful, for example, for connecting a directive receiving antenna to a receiver. Prime requisites for an effective line for use in receiving applications are small radiation resistance (or effective length) and symmetrical installation. Although the reciprocity theorem shows that the transmitting and receiving qualities of a given line are identical, it is erroneous to conclude that a negligible contribution to the radiated power when transmitting implies a negligible pickup in reception. There are fields acting on the line set up by numerous moving charges in other antennas. The interfering fields may be of sufficient amplitude to cause appreciable undesired voltage development across the input circuit of the receiver. The four-wire transmission line is particularly well suited for connecting directive receiving antennas to receivers at communication frequencies. The coaxial cable may be adapted for transferring power from the output circuit of a transmitter to a radiator (whether symmetrical or not) provided the outer surface of the coaxial cable is in contact with the surface of a highly conducting earth along its full length. Preferably the cable should be buried in the ground. If a coaxial cable is employed (having a solid copper sheath) to connect two balanced impedances, and the outer surface of the cable is not properly grounded, the line often acts like a three-conductor transmission line. (It is assumed that the frequency of the voltage applied to the sending end of the line is sufficiently high so that skin effect is an important consideration. Under these circumstances it is possible to distinguish currents flowing on the inside surface of the tube from those flowing on the outside surface of the same tube.)

As stated earlier, one important advantage of the gas-filled coaxial line over the solid dielectric cable is that its dielectric losses are lower. But this advantage is perhaps partly offset by the fact that the solid dielectric cable is more easily installed at shore radio stations. It is extremely difficult to install and maintain a gas-tight line, say 1,000 feet in length. Invariably gas leaks occur. The writer understands that an important communications company had such a difficult experience in this regard that all coaxial cables were dug up and eventually sold to a South American country in the interest of "good will relations"! The location of gas leaks along a buried coaxial cable is not a simple matter. An engineer of the concern referred to above suggested one procedure for determining the location of leaks. Bird scent (which is non-corrosive) is acquired and pumped into the line. The best available hunting dogs are then employed for finding the leaks!

The employment of flexible solid dielectric cables is advantageous, for example, in mountainous terrain and in tropical swamps, provided its relatively-high copper and dielectric losses can be tolerated. This presupposes the cable, when used for transmitting, will withstand the voltages encountered when severe mismatch conditions obtain. Radiation, or conversely pickup, are negligible if the cable is in proximity to a highly conducting earth regardless of whether balanced or unbalanced load impedances are involved. (The earth is not a good conductor at frequencies higher than those presently employed for a-m broadcasting.)

## Comments on Lines

Some engineers assume a priori that because the conventional analytical treatment of transmission lines fails to reveal certain characteristics that these are either nonexistent or at most are of no special import. For example, it is taken for granted that a "perfectly balanced open-wire line will not pick up radiations"[2] because the analysis of transmission lines based on conventional circuit theory includes no radiation phenomenon. Such an assumption is equivalent to denying the possibility of radiation from a two-element or multi-element antenna array! Likewise, such phenomenon as proximity effect (the axial asymmetrical orientation of charge about each conductor forming a line) and skin effect (except as it is reflected in the value of the attenuation factor) are ignored. (Skin effect is of importance in determining, for example, when a coaxial cable behaves like a three-conductor transmission line.) Only by a fundamental analysis of the line, based directly on Maxwell's equations are all of the factors influencing line operation determined.

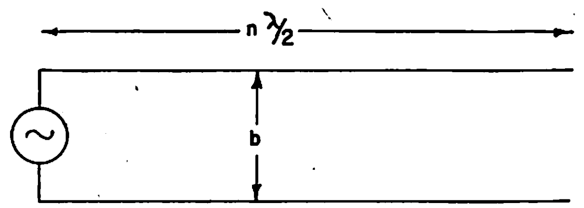

FIGURE 2A End driven two-wire transmission line a multiple of a half-wave in length. The line is open circuited at the receiving end. The current distribution along the line is essentially sinusoidally distributed.

The solution of the problem of the two-wire line as based on conventional circuit theory provides the immediate solution for the coaxial cable and for the multiple-wire, single-phase lines with regard to voltage and current distribution along the lines. Ordinarily, one derives line theory on the basis of the quasi-stationary state. On the other hand the waveguide problem is one requiring a direct application of electro-magnetic theory.

In general the currents flowing along a transmission line (for example, a two-wire line) may be of two kinds. "Transmission line currents" are defined as currents of equal magnitude but of opposite phase at a given point along the line. Currents of this type flow along lines when the lines are balanced with respect to near-by objects, and provided balanced impedances are being connected together. On the other hand, if a balanced transmission line is being used to drive an asymmetrical impedance, such as a dipole driven at some point other than the center, or to drive elements of a collinear array, "antenna currents" will flow along the line, and the line becomes part of the radiating circuit. This phenomenon might be better understood by reference to Figure 1. Here an antenna is center-driven by a two-wire line, but the line is asymmetrically arranged with respect to the antenna. The lower half of the antenna reacts on the line more than the upper half, and unbalanced line currents obtain. Suppose the current in wire (1) (where the line is sectionalized) is $I_1$, and in wire (2) it is $I_2$. Now $I_1 \neq I_2$. Define the transmission line current where the line is sectionalized $I_{1L}$ and $I_{2L}$. The antenna currents are $I_{1A}$ and $I_{2A}$. Then

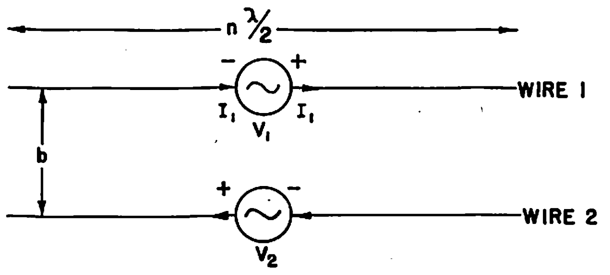

FIGURE 2B Transmission line (or two-element antenna array) driven so that the current distribution along the wires closely approximates the current distribution along the two-wire line shown in Figure 2A.

$$I_1 = I_{1L} + I_{1A}$$

$$I_2 = I_{2L} + I_{2A} = -I_{1L} + I_{1A}$$

The currents $I_{1A}$ and $I_{2A}$ are of equal amplitude and flow in the same direction. The two conductors of the line act like a single conductor antenna carrying a current $2I_{1A}$. If a coaxial line is substituted for the open wire line, current may flow on the outside surface of the cable giving rise to substantial radiation.

The ohmic loss along either the two- or four-wire line is small if the line is short regardless of how the line is terminated. Physically long lines should be operated in a non-resonant condition by terminating them in their characteristic impedances. Conversely, standing waves, from the point of view of loss, may be tolerated along physically short lines. Radiation loss (as well as ohmic loss) is a function of frequency. Radiation from two-wire transmission lines, when used in transmitting applications, may be ignored provided the line carries what might be termed a true transmission line current. (Symmetrically arranged wires do not necessarily constitute a balanced line. "Balanced" open wire lines feeding asymmetrical loads act like antennas, as explained earlier.) Radiation or conversely pickup of properly installed four-wire lines is negligible.

## Calculation of Radiation Resistance of Two- and Four-Wire Transmission Lines

The determination of the radiation resistance of an open wire transmission line is of considerable importance for by the reciprocation theorem, the radiation resistance is a direct measure of the merit of the line as a receiving antenna.

Under certain circumstances antenna theory may be applied directly to transmission lines to predict the power radiated by them. In particular, this is true for a line any integral number of half-waves in length, driven at one end and open-circuited at the other end, i.e., for 100% reflection. Happily, the current distribution is essentially sinusoidally distributed, and this may be assumed at the outset with negligible error. (In antenna theory one can not assume the current distribution to be of a certain form. One important phase of the antenna problem is to determine the current, subject to existing boundary conditions.)

The objection might be raised that a transmission line when employed for transferring power from one location to another, as distinguished from its use as an impedance transformer, is never operated under conditions of 100% reflection. This is a valid objection, but a rather intricate analysis of the problem reveals that under several specific conditions of loading, including non-resonant operation, the radiation resistance is never greater than that computed for the case of 100% reflection. This establishes a criterion for comparing in this respect, the performances of several different open-wire lines.

An anomalous result will be obtained unless the analysis for radiation from a non-resonant line is based on one of the following premises:

1—The line system (including terminations) form a closed system of conductors carrying a progressive current wave.

2—The line system does not form a closed system, but a progressive current wave exists on conductors terminated by charges, such that the condition of electrical continuity at the ends of the wires obtains.

Thus any determination of radiation resistance, purporting to apply to non-resonant transmission lines, must be based on premise (1) or (2).

Consider a two-wire transmission line an integral number of half-waves in length driven at one end and open circuited at the other end. Refer to figure 2A. The current distribution along the wires is sinusoidally distributed to a high degree of approximation, implying a vanishingly small current at each end of the line. The line as described may be replaced by an antenna array, as shown in figure 2B, composed of two symmetrical center-driven radiators. The two driving generators are identical and maintain the flow of currents of equal amplitude, but of opposite phase along the wires. The current distribution along the wires of the two element close-spaced array (figure 2B) is not significantly different from the current distribution along the transmission line (figure 2A). The radiation resistance of the line is the same as the radiation resistance of the array, and the latter may be easily determined in terms of the available expressions for mutual and self-impedance for coupled antennas. It is to be observed that the generators are located at a current node (point of high impedance). Expressions for mutual and self-impedance, based on the assumption of a sinusoidal current distribution are meaningless when referred to a

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[2] See, for example, "R.F. Goes Underground," Pages 32 to 35, October 1948, BuShips Electron.

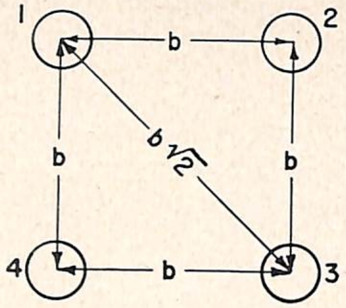

FIGURE 3 Four-wire transmission line. The wires are oriented at the corners of a square. Diagonal wires are connected in parallel.

current node; accordingly, such formulas are referred to a maximum current existing along the radiator. The first current maximum exists one quarter wave-length from the free ends of either antenna. Referring now to figure 2B, the relation between the voltages $V_1$ and $V_2$ and the currents $I_1$ and $I_2$ are given by

$$V_1 = I_1Z_{11} + I_2Z_{12}$$
$$V_2 = I_2Z_{22} + I_1Z_{21}$$

Here $V_1$ and $V_2$ are the voltages applied at the centers of wires 1 and 2 respectively. $I_1$ and $I_2$ are the currents flowing into or out of the input terminals located at the centers of wires 1 and 2, respectively. $Z_{11}$ is the self-impedance of antenna 1; $Z_{22}$ is the self-impedance of antenna 2; and $Z_{12} = Z_{21}$ is the mutual impedance of wires 1 and 2.

In the present case $V_1 = -V_2$, $I_1 = -I_2$, $Z_{11} = Z_{22}$ and $Z_{12} = Z_{21}$.

Accordingly,

$$V_1 = I_1Z_{11} - I_1Z_{12} = I_1(Z_{11} - Z_{12}).$$

The input impedance of antenna 1 is

$$Z_1 = V_1/I_1 = Z_{11} - Z_{12}.$$

It is evident that the input impedance of antenna 2 is precisely the same as the input impedance of antenna 1 because of symmetry.

The power radiated by wire 1 is

$$P_1 = I_1^2(R_{11} - R_{12})$$

where $R_{11}$ is the resistive component of the self-impedance, and $R_{12}$ is the resistive component of the mutual impedance.

The power radiated by wire 2 is the same as the power radiated by wire 1. Hence the total power radiated is

$$P_0 = 2I_1^2(R_{11} - R_{12})$$

and the radiation resistance referred to the line current at a point of current maximum is

$$R_{\text{max (2 wire line)}} = P_0/I_1^2 = 2(R_{11} - R_{12}) \quad (1)$$

From elementary theory of the multiple half-wave antenna

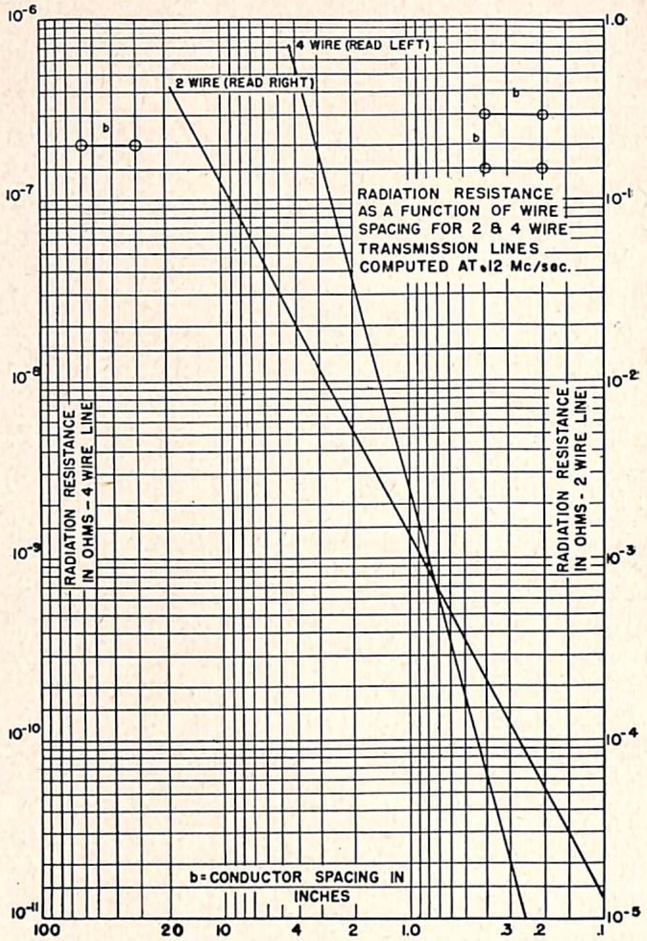

FIGURE 4 Radiation resistance (referred to the current maximum) of two- and four-wire transmission lines as a function of wire spacing at 12 Mc/sec.

$$R_{11} = 30 \left\{ 0.5772 + \log_e 4\beta h - \text{Ci}4\beta h \right\} \ldots\ldots (2)$$

$$R_{12} = 30 \left\{ 2\text{Ci}\beta b - \text{Ci}\beta\left(\sqrt{(2h)^2+b^2}+2h\right) - \text{Ci}\,\beta\left(\sqrt{(2h)^2 + b^2} - 2h\right)\right\} \ldots\ldots (3)$$

Here $\beta = 2\pi/\lambda$, $\lambda$ is the wavelength, h is the antenna half-length, (i. e., the overall length of the transmission line is 2h) and b is the distance between wires, measured center-to-center.

For small values of x, $(-17 \leqq x \leqq 17)$ the following series are good approximations for Ci(x) and Si(x):

$$\text{Ci}(x) = 0.5772 + \log_e x - \frac{1}{2}\frac{x^2}{2!} + \frac{1}{4}\frac{x^4}{4!} - \ldots (4)$$

$$\text{Si}(x) = x - \frac{1}{3}\frac{x^3}{3!} + \frac{1}{5}\frac{x^5}{5!} - \ldots\ldots\ldots\ldots (5)$$

If only an approximate expression is required for the radiation resistance of the two-wire line, only the leading terms of the expansions for Ci(x) and Si(x), as given by (4) and (5) need be retained, and when it is remembered that $2h >> b$, a great simplification in the resulting equations may be secured, since it is permissible to neglect all terms involving small quantities. $\left\{\text{Note that when } b << 2h,\ \beta\left(\sqrt{(2h)^2 + b^2} + 2h\right) \doteq 4\beta h \text{ and } \beta\left(\sqrt{(2h)^2 + b^2} - 2h\right) \doteq \frac{\beta b^2}{4h}\right\}$

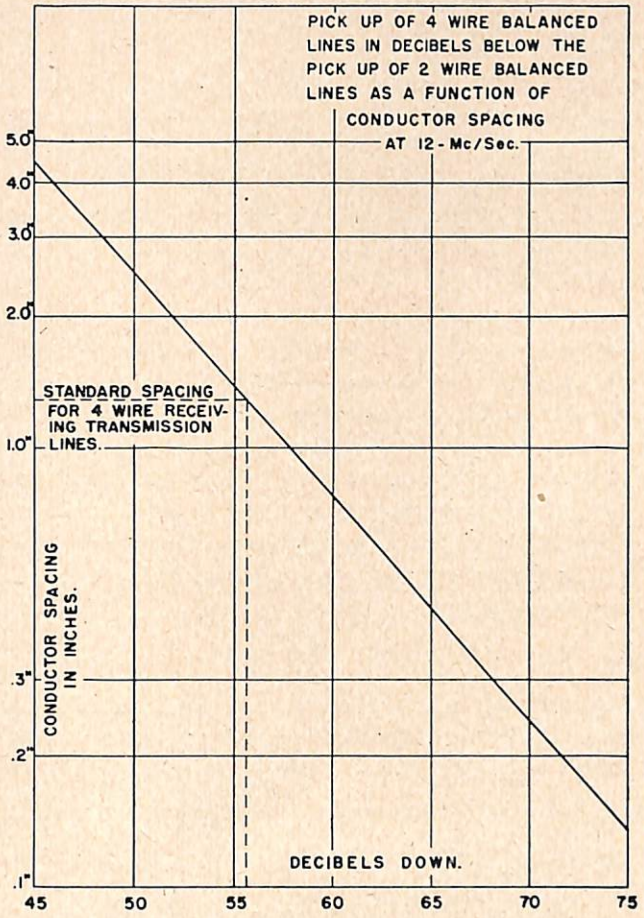

FIGURE 5 Comparison of two- and four-wire lines on the basis of relative pickup at 12 Mc/sec.

Care must be exercised, however, to insure that a sufficient number of terms of higher order than the second power are retained, for otherwise when forming an expression for the radiation resistance of a particular multiple wire line, the result may vanish.

When this procedure is followed the radiation resistance for a two-wire line is found to be

$$R_{\text{max (2 wire line)}} = 120\pi^2 \left(\frac{b}{\lambda}\right)^2 \text{ohms} \ldots\ldots\ldots (6)$$

The radiation resistance of a four-wire single phase transmission line may be determined as follows: Refer to figure 3. Wires 1 and 3 are connected in parallel and wires 2 and 4 are connected in parallel, i.e., conductors of the same polarity lie diagonally opposite each other. (If wire 1 carries a current in phase with the current in wire 2, and these currents flow in the opposite direction with regard to the currents flowing in wires 3 and 4, little advantage is achieved over the use of a simple two-wire line and this case will not be considered here.) The four-wire transmission line is now replaced by a four-element antenna array, each element of which is center-driven and carries currents of the same magnitude, but of the requisite phase.

Employing the previously used notation one has

$$V_1 = I_1Z_{11} + I_2Z_{12} + I_3Z_{13} + I_4Z_{14}$$

But

$$I_1 = I_3 = -I_2 = -I_4$$

and

$$Z_{12} = Z_{14}$$

Accordingly,

$$V_1 = I_1(Z_{11} + Z_{13} - 2Z_{12})$$

The input impedance is

$$Z_1 = V_1/I_1 = Z_{11} + Z_{13} - 2Z_{12}$$

or the input resistance is

$$R_1 = R_{11} + R_{13} - 2R_{12}$$

The power radiated by wire 1 is obtained from

$$P_1 = I_1^2 R_1 = I_1^2 (R_{11} + R_{13} - 2R_{12})$$

and by symmetry the total power radiated, referred to the maximum current existing in one wire of the four-wire line, is

$$P_0 = 4I_1^2 (R_{11} + R_{13} - 2R_{12})$$

But the *line current* $I_0$ is twice the current existing in one wire, i.e., $I_0 = 2I_1$, $I_0^2 = 4I_1^2$. Therefore, the power radiated, referred to the total line current, is

$$P_0 = I_0^2 (R_{11} + R_{13} - 2R_{12})$$

and the radiation resistance, referred to the maximum value of the total line current, is given by

$$R_{\text{max (4 wire line)}} = P_0/I_0^2 = R_{11} + R_{13} - 2R_{12} \ldots\ldots\ldots\ldots (7)$$

When the calculations are completed, subject to similar approximative processes employed in the case of the two-wire line, one finds that the radiation resistance of a four-wire transmission line is

$$R_{\text{max (4 wire line)}} = 20\pi^4 \left(\frac{b}{\lambda}\right)^4 \text{ohms.}$$

It is apparent, from a consideration of the equations for the radiation resistance of two- and four-wire transmission lines that the power radiated by a four-wire line is extremely small compared to that radiated by a two-wire line, for the same frequency and comparable spacing. By use of the reciprocity theorem, the signal pickup of a four-wire line is extremely small compared to the pickup of a two-wire line. The pickup of the four-wire line, in decibels below the pickup of a two-wire line of the same spacing is

$$\text{db} = 10 \log_{10} \left(\frac{6\lambda^2}{\pi^2 b^2}\right) \ldots\ldots\ldots\ldots (8)$$

Two- and four-wire transmission lines are compared on the basis of their radiation resistances and their relative pickups in figures (4) and (5).

## Characteristic Impedance of Conventional Transmission Lines

The behavior of a transmission line depends in part on the characteristic impedance of the line. This impedance is a pure resistance if the line is presumed to be lossless, i.e., $Z_c = R_c$.

For a two-wire transmission line the characteristic impedance $Z_c$ is

$$Z_c = 276 \log_{10} \frac{b}{a} \text{ohms} \ldots\ldots\ldots\ldots\ldots (9)$$

Here b is the distance between wires, measured center to center. a is the radius of the wires employed.

The characteristic impedance of a four-wire line is

$$Z_c = (138 \log_{10} \frac{b}{a}) - 20.78 \text{ ohms} \ldots\ldots (10)$$

Thus the characteristic impedance is 20.78 ohms less than one half the characteristic impedance of a two-wire line having the same wire spacing. (The above formulas are valid only when $b \geqq 10$ a).

The characteristic impedance of a concentric cable is

$$Z_c = \frac{138}{\sqrt{\varepsilon_r}} \log_{10} \frac{b}{a} \text{ohms} \ldots\ldots\ldots\ldots\ldots (11)$$

where b is the distance between the center of the inside conductor to the inside surface of the outer tube, a is the radius of the center conductor and $\varepsilon_r$ is the relative dielectric constant, 1 for air.

The characteristic resistances of two- and four-wire lines are shown in figures (6) and (7) respectively. Notice that the range of coverage is different for the two lines. The coaxial cable further extends the range of characteristic resistance downward. The importance of the four-wire line as an impedance transformer should not be ignored. For example, suppose it is desired to match a resonant center-driven dipole having an input resistance of 70 ohms to a two-wire transmission line having a characteristic resistance of 600 ohms. A quarter-wave transformer may be employed for this purpose. The characteristic resistance of the quarter-wave transformer is given by

$$R_c = \sqrt{70 \times 600} \doteq 205 \text{ ohms.}$$

Reference to figure (7) reveals that this value of $R_c$ is well within the range of four-wire transmission lines having various design parameters.

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[1] Reprinted from the May 1949 issue of the "Journal of the American Society of Naval Engineers" by permission of the ASNE.

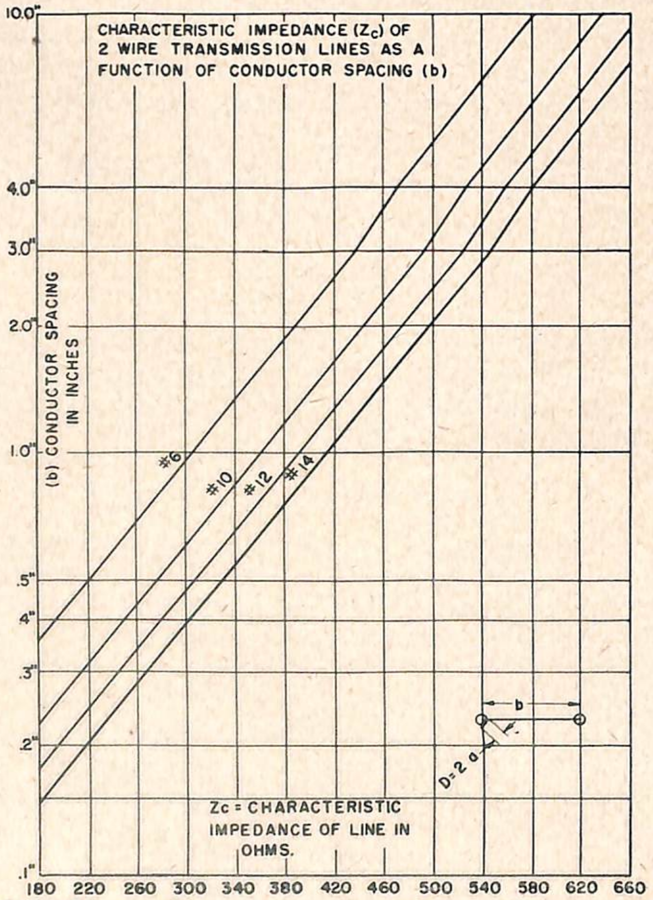

FIGURE 6 Characteristic impedance of two-wire transmission lines.

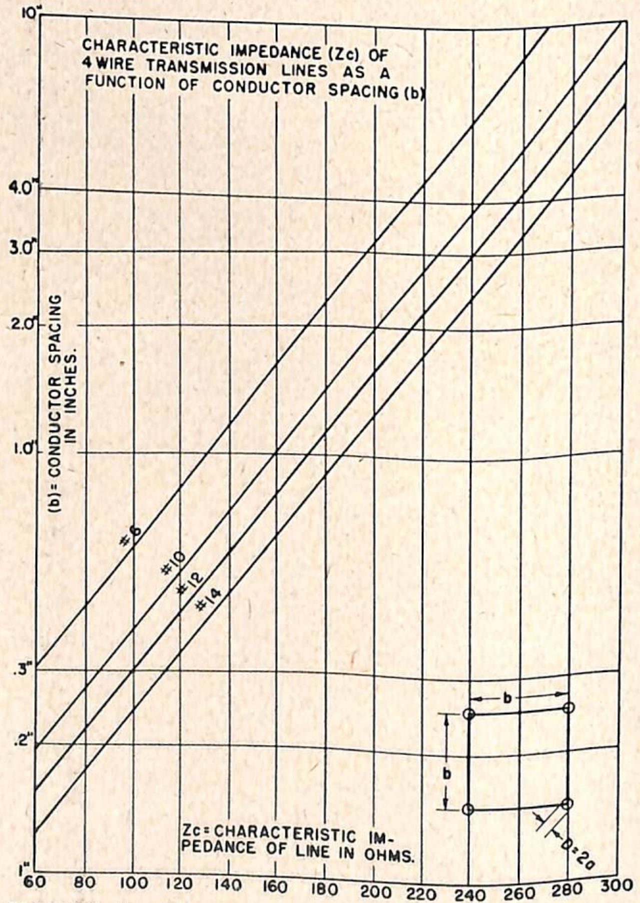

FIGURE 7 Characteristic impedance of four-wire transmission lines.

# NEW BOOKS

The BuShips Electron of December 1947 contained a list of all instruction books distributed from 1 October 1945 to 1 September 1947. The following pages list all instruction books distributed from 1 September 1947 to 1 June 1949. The first part of this list includes all equipments bearing a Navy model letter, Navy type number, or a joint Army-Navy designation. The second part includes equipments bearing only commercial designations. The key to the abbreviations appearing under *"Edition"* in each list is given in the next column.

Supplementary lists will be published in BuShips Electron at regular intervals, as additional instruction books are distributed.

| | |
|---|---|
| C | Commercial Publication |
| Ch. | Change |
| CI | Complimentary Instructions |
| DB | Descriptive Booklet |
| F | Final Book |
| FC | Field Change |
| FCB | Field Change Bulletin |
| IB | Instruction Book |
| IH | Installation Handbook |
| IS | Instruction Sheets |
| MH | Maintenance Handbook |
| MI | Maintenance Instructions |
| OH | Operators' Handbook |
| P | Preliminary Instruction Book |
| RS | Revision Sheets |
| S | Supplement |
| SP | Spare Parts Catalogue |
| T | Temporary |
| TM | Technical Manual |
| * | Limited Quantities Only |

## PART I

| *Model* | *Short Title* | *Edition* |
|---|---|---|
| AM–215/U | NAVSHIPS 91,078 | F |
| AM–215/U | NAVSHIPS 900,995 | F |
| AN/APX–7(XN–21) | | MI |
| AN/ARD–4 | AN–16–30ARD–4–3 | MH |
| AN/BQS–T2 | NAVSHIPS 91.055 | F |
| AN/BQS–T3 | NAVSHIPS 91,107 | F |
| AN/CPX–3(XN–21) | NAVSHIPS 900,940 | RS |
| AN/CPX–4(XN–21) | NAVSHIPS 900,941 | RS |
| AN/CPX–11(XN–21) | NAVSHIPS 91,079 | F |
| AN/GMQ–2 | NAVSHIPS 900,944(A) | F |
| AN/GMQ–2 | 900,944(A) | Ch. 1 |
| AN/MPN–1A | SHIPS 316(A) | T. Ch. T–2 |
| AN/MPN–1A | NAVSHIPS 316(A) | Ch. 2 to IB |
| AN/MPN–1A | NAVSHIPS 316(A) | Ch. 3 to IB |
| AN/MPN–1A | NAVSHIPS 98,025 | FC #2 |
| AN/MPN–1A | NAVSHIPS 98,104 | FCB #6 |
| AN/MPN–4(XN–1) | NAVSHIPS 91,195 | F |
| *AN/MPX–2(XN–21) | NAVSHIPS 91,057 | F |
| AN/MRD–8 | NAVSHIPS 900,939(A) | F |
| AN/PDR–2 | NAVSHIPS 91,039 | F |
| AN/PDR–3 | NAVSHIPS 91,017 | F |
| AN/PDR–3A | NAVSHIPS 91,133 | F |
| AN/PDR–4 | NAVSHIPS 91,018 | F |
| AN/PDR–5 | NAVSHIPS 91,012 | F |
| AN/PDR–6 | NAVSHIPS 91,019 | F |
| AN/PDR–7 | NAVSHIPS 91,040 | F |
| AN/PPN–8(XN–21) | NAVSHIPS 900,978 | MI |
| *AN/PPN–8(XN–21) | NAVSHIPS 900,978 | Ch. 1 |
| AN/SGC–1 | NAVSHIPS 91,152 | F |
| AN/SPN–4 | NAVSHIPS 91,052 | F |
| AN/SPS–6 | NAVSHIPS 91,064 | F |
| AN/SPS–6 | NAVSHIPS 98,107 | FCB #1 |
| AN/SPS–6 | NAVSHIPS 98,109 | FCB #2 |
| AN/SPS–6 | NAVSHIPS 98,114 | FCB #6 |
| AN/SPS–6 | NAVSHIPS 98,113 | FCB #8 |
| AN/SPS–6 | NAVSHIPS 98,112 | FCB #10 |
| AN/SPS–6 | NAVSHIPS 98,116 | FCB #11 |
| AN/SPS–6 | NAVSHIPS 98,117 | FCB #12 |
| AN/SPS–6 | NAVSHIPS 98,118 | FCB #13 |
| AN/SPS–6/–6A/–6B | NAVSHIPS 91,081 | F |
| AN/SPS–6/–6A/–6B | NAVSHIPS 91,081.2 | OH |
| AN/SPS–6/–6A/–6B | NAVSHIPS 91,081.3 | MH |
| AN/SPS–6/–6A/–6B | NAVSHIPS 91,081.4 | SP |
| AN/SPX–1(XN–21) | NAVSHIPS 900,965 | F |
| *AN/SPX–1(XN–21) | NAVSHIPS 900,965 | Ch. 1 |
| AN/SPX–2(XN–21) | NAVSHIPS 900,966 | F |
| AN/SPX–2(XN–21) | NAVSHIPS 900,966 | Ch. 1 |
| AN/SRQ–2 | NAVSHIPS 900,971 | F |
| AN/TPS–1B | NAVSHIPS 4D–46 | FC #4 |
| AN/TPS–1B | NAVSHIPS 28–45 | FC #5 |
| AN/TPS–1B | NAVSHIPS 98,064 | FC #7 |
| AN/TPX–8 | NAVSHIPS 91,063 | NRL Report |
| AN/TXC–1B | NAVSHIPS 91,068 | TM |
| AN/UDR–2 | NAVSHIPS 91,042 | F |
| AN/UPA–1A | NAVSHIPS 91,049 | F |
| *AN/UPA–4(XN–21) | NAVSHIPS 91,015 | F |
| AN/UPA–5(XN–1) | NAVSHIPS 900,966 | P |
| AN/UPA–5(XN–1) | NAVSHIPS 900,977(A) | F |
| AN/UPA–9(XN–1) | NAVSHIPS 900,984 | F |
| AN/UPA–9(XN–1) | NAVSHIPS 900,984 | Ch. 1 |
| AN/UPA–10(XN–1) | NAVSHIPS 900,985(A) | F |
| AN/UPA–11(XN–21) | NAVSHIPS 900,964 | F |
| AN/UPA–11(XN–21) | NAVSHIPS 900,961 | T. Ch. T–1 |
| AN/UPA–16(XN–21) | NAVSHIPS 900,875 | F |
| AN/UPA–16(XN–21) | NAVSHIPS 900,875.4 | SP |
| AN/UPA–20(XN–21) | NAVSHIPS 900,875 | F |
| AN/UPA–20(XN–21) | NAVSHIPS 900,875.4 | SP |
| AN/UPM–4(XN–21) | NAVSHIPS 900,949 | RS |
| AM/UPM–6(XN–21) | NAVSHIPS 900,951 | F |
| AN/URH–1 | NAVSHIPS 91,132(A) | F |
| AN/USM–3 | 91,146 | F |
| AS–294(XN–21)/UP | NAVSHIPS 900,964 | F |

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|---|---|---|
| AS–295(XN–21) | NAVSHIPS 900,961 | T. Ch. T–1 |
| AS–295(XN–21)/UP | NAVSHIPS 900,964 | F |
| BC–638A | NAVSHIPS 91,046 | F |
| CP–38/UD | NAVSHIPS 91,029 | C |
| CXJG | NAVSHIPS 900,846 | Ch. 1 |
| CXJW | NAVSHIPS 91,166 | F |
| CXJY | NAVSHIPS 91,056 | F |
| 23AGU | NAVSHIPS 900,879(A) | Ch. 1 |
| DBF | NAVSHIPS 900,929 | F |
| DBF–1 | NAVSHIPS 900,859 | F |
| FR–1/U | (Stocked by USMC only) | F |
| FRF | NAVSHIPS 98,027 | FC #1 |
| FSB | NAVSHIPS 900,928 | F |
| IM–4/PD | NAVSHIPS 91,033 | F |
| IM–7/PD | NAVSHIPS 91,016 | F |
| JAA | NAVSHIPS 900,997 | F |
| KY–32/GRT | NAVSHIPS 91,109 | F |
| KY–43/URT | NAVSHIPS 91,138 | F |
| LAE–3/–4 | NAVSHIPS 900,806 | Ch. 2 |
| LAF/–3 | NAVSHIPS 900,516 | F |
| LAJ–1 | NAVSHIPS 900,956 | Ch. 1 |
| LAJ–2 | NAVSHIPS 91,143 | F |
| LP–5 | NAVSHIPS 900,425 | Ch. 1 |
| LR–3 | NAVSHIPS 91,136 | F |
| LX–2 | NAVSHIPS 91,130 | F |
| Mark 2, Mod. 0 | NAVSHIPS 91,122 | F |
| Mk 2 Mod. 1 | NAVSHIPS 91,140.4 | SP |
| Mark 2 Mod. 2 Radar | NAVSHIPS 900,926 | F |
| Mark 8, Mod. 2 & 4 | NAVSHIPS 900,967 | F |
| Mark 25, Mod. 2 | NAVSHIPS 900,975 | F |
| ME–2/U | NAVSHIPS 91,095 | C |
| ME–6/U | NAVSHIPS 95,564 | C |
| ME–11/U | NAVSHIPS 91,118 | F |
| ME–25/U | NAVSHIPS 91,159 | F |
| MN–1B (Electronic Navigator) | NAVSHIPS 91,117 | C |
| MU (Marine Radar) | NAVSHIPS 91,121 | C |
| MX–833/SL | NAVSHIPS 900,999 | F |
| MX–836/TPS–1B | NAVSHIPS 91,067 | F |
| MX–853/SPN–4 | NAVSHIPS 91,052 | F |
| NGA | NAVSHIPS 900,662 | F |
| NGA | NAVSHIPS 900,662.1 | IH |
| NGA | NAVSHIPS 900,662.2 | OH |
| NGA | NAVSHIPS 900,662.2 | MH |
| NGA | NAVSHIPS 900,662.4 | SP |
| NGA–1 | NAVSHIPS 91,048 | F |
| NGA–1 | NAVSHIPS 91,048.2 | OH |
| NGB/NGB–1/2/3 | NAVSHIPS 91,014(A) | F |
| NGB/NGB–1/2/3 | NAVSHIPS 91,014(A) | T. Ch. T–1 |
| NGB/NGB–1/2/3 | NAVSHIPS 91,014(A) | T. Ch. T–2 |
| NK–6 | NAVSHIPS 900,334(A) | F |
| NMC | NAVSHIPS 98,090 | FCB #8 |
| O–76/U | NAVSHIPS 91,124 | C |
| OBE | NAVSHIPS 900,312 | F |
| OBQ–4 | NAVSHIPS 900,988 | F |
| OCJ | NAVSHIPS 900,996 | F |
| OCQ | NAVSHIPS 91,134 | F |
| OCT–2/–3 | NAVSHIPS 91,131 | F |
| OCT–2/3 | NAVSHIPS 91,131 | Ch. 1 |
| OCY–1 | NAVSHIPS 91,011 Vol. 1 | F |
| OCY–1 | NAVSHIPS 91,011 | F |
| OCZ | NAVSHIPS 900,955 | F |
| OCZ | NAVSHIPS 900,955 | T. Ch. T–1 |
| OJ–3 | NAVSHIPS 900,994 | F |
| OKA | NAVSHIPS 98,130 | FC #3 |
| OMA | NAVSHIPS 91,027 | F |
| OMA | NAVSHIPS 98,115 | FCB #1 |
| OS–9/U | NAVSHIPS 91,135 | F |
| PF | NAVSHIPS 900,922 | F |
| PP–286/UR | | F |
| PP–388/U | NAVSHIPS 91,137 | F |
| PP–388/U | NAVSHIPS 91,066 | F |
| PQ/PQ–1 | NAVSHIPS 900,622(A) | F |
| PU–66/U | NAVSHIPS 95,212 | C |
| PU–155(XN–1)/SP | NAVSHIPS 91,100 | F |
| QDA | NAVSHIPS 900,700 | Ch. 1 |
| QDA | NAVSHIPS 900,700.1 | Ch. 1 |
| QDA | NAVSHIPS 900,700.2 | Ch. 1 |
| QDA | NAVSHIPS 900,700.3 | Ch. 1 |
| QDA | NAVSHIPS 900,700.4 | Ch. 1 |
| QDA | NAVSHIPS 98,086 | FC #2 |
| QGB | NAVSHIPS 98,081 | FC #18 |
| QHB | NAVSHIPS 900,976 | F |
| QHB | NAVSHIPS 98,082 | FC #3 |
| QHB | NAVSHIPS 98,110 | FCB #4 |
| QHB | NAVSHIPS 98,121 | FCB #5 |
| QHB/QHB–1 | NAVSHIPS 900,976(A) | F |
| QXA | NAVSHIPS 900,903 | F |
| QXB | NAVSHIPS 91,076 | F |
| R–223/SPR Radar Receiver | NAVSHIPS 900,991 | F |
| R–247/URR | NAVSHIPS 91,084 | F |
| RBA–5/6 | NAVSHIPS 900,708 | F |
| RBA–5/6 | NAVSHIPS 900,708 | Ch. 1 |
| RBB–3/4 and RBC–3/4 | NAVSHIPS 91,101 | F |
| RBM–1/2/3/4/5 | NAVSHIPS 900,381 | T–1 |
| RBM–1/2/3/4/5 | NAVSHIPS 98,066 | FC #1 |
| RDC–1 | NAVSHIPS 900,486 | F |
| RDC–1 | NAVSHIPS 900,486 | Ch. 1 |
| RDH | NAVSHIPS 91,070 | F |
| RDM–1 | NAVSHIPS 91,061 | F |
| RDR | NAVSHIPS 900,841(A) | F |
| REM | NAVSHIPS 91,003 | P |
| REM | NAVSHIPS 91,003(A) | F |
| RR–29AM | NAVSHIPS 91,045 | C |
| RR–30/AM | NAVSHIPS 91,102 | DB |
| SA–160/U | NAVSHIPS 91,096 | F |
| SA–160/U | NAVSHIPS 91,096 | Ch. 1 |
| SC–4 | NAVSHIPS 900,866 | F |
| SC–4 | NAVSHIPS 900,866.4 | SP |
| SC–5 | NAVSHIPS 900,867 | F |
| SC–5 | NAVSHIPS 900,867.4 | SP |
| SG–2B | NAVSHIPS 98,084 | FC #63 |
| SG–3 | SHIPS 367–A | Ch. 1 |
| SG–3 | NAVSHIPS 900,899.3 | Ch. 1 |
| SG–3 | NAVSHIPS 98,083 | FC #2 |
| SG–17/U | NAVSHIPS 91,085 | F |
| SG–18/U | NAVSHIPS 91,112 | F |
| SK–3 | NAVSHIPS 900,919 | F |
| SK–3 | NAVSHIPS 900,919.4 | SP |
| SP–1M | NAVSHIPS 900,560 | F |
| SP–1M | NAVSHIPS 900,560.4 | SP |
| SR/SRa | NAVSHIPS 900,946 | F |
| SR–2 | NAVSHIPS 900,577(A) | Ch. 1 |
| SR–2 | NAVSHIPS 900,577(A).1 | Ch. 1 |
| SR–2 | NAVSHIPS 900,577(A).2 | Ch. 1 |
| SR–2 | NAVSHIPS 900,577(A).3 | Ch. 1 |
| SR–2 | NAVSHIPS 900,577(A).4 | Ch. 1 |
| SR–2 | NAVSHIPS 98,068 | FC #2 |
| SR–2 | NAVSHIPS 98,069 | FC #3 |
| SR–3 | NAVSHIPS 900,539 | Ch. 1 |
| SR–6 | 98,098 | FC #3 |
| SR–6 | 98,099 | FC #4 |
| SR–6 | NAVSHIPS 900,989 | F |
| SR–6 | NAVSHIPS 900,989.1 | IH |
| SR–6 | NAVSHIPS 900,989.2 | OH |
| SR–6 | NAVSHIPS 900,989.3 | MH |
| SR–6 | NAVSHIPS 900,989.4 | SP |
| SR–6 | NAVSHIPS 900,989 | Ch. 1 |
| SR–6 | NAVSHIPS 900,989.1 | Ch. 1 |
| SR–6 | NAVSHIPS 900,989.2 | Ch. 1 |
| SR–6 | NAVSHIPS 900,989.3 | Ch. 1 |
| SR–6 | NAVSHIPS 900,989.4 | Ch. 1 |
| SR–6 | NAVSHIPS 98,103 | FC #6 |
| SR–6 | NAVSHIPS 98,106 | FCB #6 |
| SU–2 & X–SU–2 | NAVSHIPS 900,831(A) | F |
| SU–2 & X–SU–2 | NAVSHIPS 900,831(A).1 | IH |
| SU–2 & X–SU–2 | NAVSHIPS 900,831(A).2 | OH |
| SU–2 & X–SU–2 | NAVSHIPS 900,831(A).4 | SP |
| SX | NAVSHIPS 98,087 | FCB #6 |
| SX | NAVSHIPS 98,108 | FCB #7 |
| (Frequency-Shift Oscillator for TBA) | NAVSHIPS 900,206 | F |
| TBC–3 | NAVSHIPS 900,855 | F |
| (Frequency-Shift Oscillator for TBK) | NAVSHIPS 900,205 | F |
| TDN–2/–3/–4 | NAVSHIPS 900,709 | F |
| TDZ | NAVSHIPS 900,809 | F |
| TDZ | NAVSHIPS 900,809 | Ch. 1 |
| TEH | NAVSHIPS 91,116 | F |
| TPA | NAVSHIPS 900,962(A) | F |
| TS–107/TPM–1 | NAVSHIPS 900,454(A) | F |
| TS–130/UP | NAVSHIPS 900,538 | F |
| TS–147A/UP | NAVSHIPS 91,104 | F |
| TS–218A/UP | NAVSHIPS 91,083 | F |
| TS–230A/AP | NAVSHIPS 91,105 | F |
| TS–239A/UP | NAVSHIPS 91,148 | F |
| TS–295/UP | SHIPS 311(A) | F |
| TS–295A/UP | NAVSHIPS 91,164 | F |
| TS–311A/UP | NAVSHIPS 91,111 | F |
| TS–318/UP and TS–365/UP | NAVSHIPS 91,089 | F |
| TS–324 | NAVSHIPS 91,006 | F |
| TS–349/UP | NAVSHIPS 900,884 | F |
| TS–349/UP | NAVSHIPS 900,884 | Ch. 1 |
| TS–373(XN–21)/UP | NAVSHIPS 91,106 | F |
| TS–383A/GG | NAVSHIPS 91,161 | F |
| TS–403/U | NAVAER AN–16/35TS403–3 | MH |
| TS–535/U | NAVSHIPS 900,855 | F |
| TS–535/U | NAVSHIPS 900,839 | Ch. 1 |
| TS–587/U & TS–587A/U | NAVSHIPS 900,990 | F |
| TS–587/U & TS–587A/U | NAVSHIPS 900,990 | Ch. 1 |
| TS–629/U | NAVSHIPS 91,072 | F |
| TS–659/UG | NAVSHIPS 91,162 | F |
| TS–660/UG | NAVSHIPS 91,157 | F |
| TT–23/SG | NAVSHIPS 91,103 | F |
| VK | NAVSHIPS 900,986 | F |
| VK Mod for Evaluation of AN/ARR–27 | NAVSHIPS 91,203 | F |
| WFA–a | NAVSHIPS 900,448(A) | F |
| WFA–a | NAVSHIPS 900,448(A) | OH |
| WFA–1 | NAVSHIPS 900,963(A) | F |
| WFA–1 | NAVSHIPS 98,080 | FC #1 |
| WFA–1 | NAVSHIPS 900,963(A).2 | OH |
| X–MBT | NAVSHIPS 91,115 | F |
| XSO–5 | NAVSHIPS 900,970 | F |
| XSO–5 | NAVSHIPS 900,970.2 | OH |
| XTEG/XTEG–1 | NAVSHIPS 900,958 | F |
| X–VK | NAVSHIPS 900,993 | F |
| 2M–4/U | NAVSHIPS 91,073 | C |
| –14ACN | NAVSHIPS 91,010 | F |
| –55AHP–1 | NAVSHIPS 900,827 | Ch. 2 |
| –55AHP–1 | NAVSHIPS 900,827.4 | Ch. 2 |
| –60ACZ–1 | NAVSHIPS 900,983 | F |
| –60ADM | NAVSHIPS 900,992 | F |
| –66AMX(Antenna) | NAVSHIPS 900,947 | F |
| –10035B | NAVSHIPS 91,059 | F |
| –10646 | NAVSHIPS 91,013 | T. Ch. |
| –20437 | NAVSHIPS 900,943 | F |
| –21048 | NAVSHIPS 91,059 | F |
| –21356 | NAVSHIPS 91,059 | F |
| –23496 | NAVSHIPS 95,006 | F |
| –23510 | NAVSHIPS 900,206(X) | F |
| –35131 | NAVSHIPS 91,144 | C |
| –49546 | NAVSHIPS 900,618(A) | C |
| –49992(for OE) | NAVSHIPS 900,781(A) | F |
| –50308A(for TDO) | NAVSHIPS 900,973 | F |
| –51080 | NAVSHIPS 900,735(A) | F |
| –53518(for RDR/MAR) | NAVSHIPS 900,998 | F |
| –53538 | NAVSHIPS 91,065 | C |
| –60094 | NAVSHIPS 95,437 | C |
| –60139 | NAVSHIPS 900,735(A) | F |
| –73029 | NAVSHIPS 900,753 | F |
| –78269 | NAVSHIPS 91,002 | F |
| No. 105382 Modification Kit for Teletype Automatic Carriage Return & Line Feed | NAVSHIPS 91,025 | IS |
| –211504 | NAVSHIPS 91,002 | F |
| –471138 | NAVSHIPS 900,972 | F |
| –471138 | NAVSHIPS 900,972 | Ch. 1 |

## PART 2

| *Model* | *Short Title* | *Edition* |
|---|---|---|
| Amplifier, Linear (204A) | NAVSHIPS 91,120 | F |
| Brush Transient Recorder, BL–502 | NAVSHIPS 91,092 | F |
| Control Unit for Use With Single Side Band Rcvr. | NAVSHIPS 91,182 | F |
| Dual Beam CRO, Type 279 | NAVSHIPS 91,150 | F |
| Dumont 185 Electronic Switch | NAVSHIPS 95,554 | F |
| Electronic Timer for AN/FGC–1A/–1B, KS 15206 | NAVSHIPS 91,024 | F |
| FM Mobile Equip't. | NAVSHIPS 91,071 | F |
| Impedance Bridge, W.E. Type O–170370 | NAVSHIPS 91,142 | F |
| Ink Recorder and Pulse Analyzer, MA–126–E | NAVSHIPS 91,008 | CI |
| Link Xmtr-Rcvr Unit, FMATR–30–D | NAVSHIPS 91,098 | F |
| Link Xmtr-Rcvr Unit, FSATR–50–BR | NAVSHIPS 91,097 | F |
| Marine Radar Equipment, CR–101 | NAVSHIPS 91,129 | F |
| Metal-Clad Switch Gear G.E. Type MI–6 | NAVSHIPS 900,953 | F |
| PTT–RATT | NAVSHIPS 91,181 | F |
| Remote Control for FSATR–50–BR, P–8274–F | NAVSHIPS 91,099 | F |
| RF & AF Signal Distribution Unit | NAVSHIPS 91,047 | F |
| Scaler, 101A | NAVSHIPS 91,119 | F |
| Scaling Unit, IDL type 162 | NAVSHIPS 91,153 | F |
| Scaling Unit, IDL type 163 | NAVSHIPS 91,154 | F |
| Scaling Unit, IDL type 164 | NAVSHIPS 91,155 | F |
| Six Channel Oscillograph Instrument, BL–216 | NAVSHIPS 91,091 | F |
| Teletype, Model 15, Manual 67 | NAVSHIPS 91,128 | F |
| Teletype Distortion Test Set DXD4DTS | NAVSHIPS 91,058 | F |
| Teletype Transmitter Distributor, Model 14 | NAVSHIPS 98,028 | F |
| Transmitter-Receiver, 25–UFS | NAVSHIPS 91,070 | F |
| Transmitter-Receiver, 50–UFS | NAVSHIPS 91,069 | F |

# NAVAL ELECTRONICS

IS RISING TO NEW HEIGHTS TO MEET THE FUTURE