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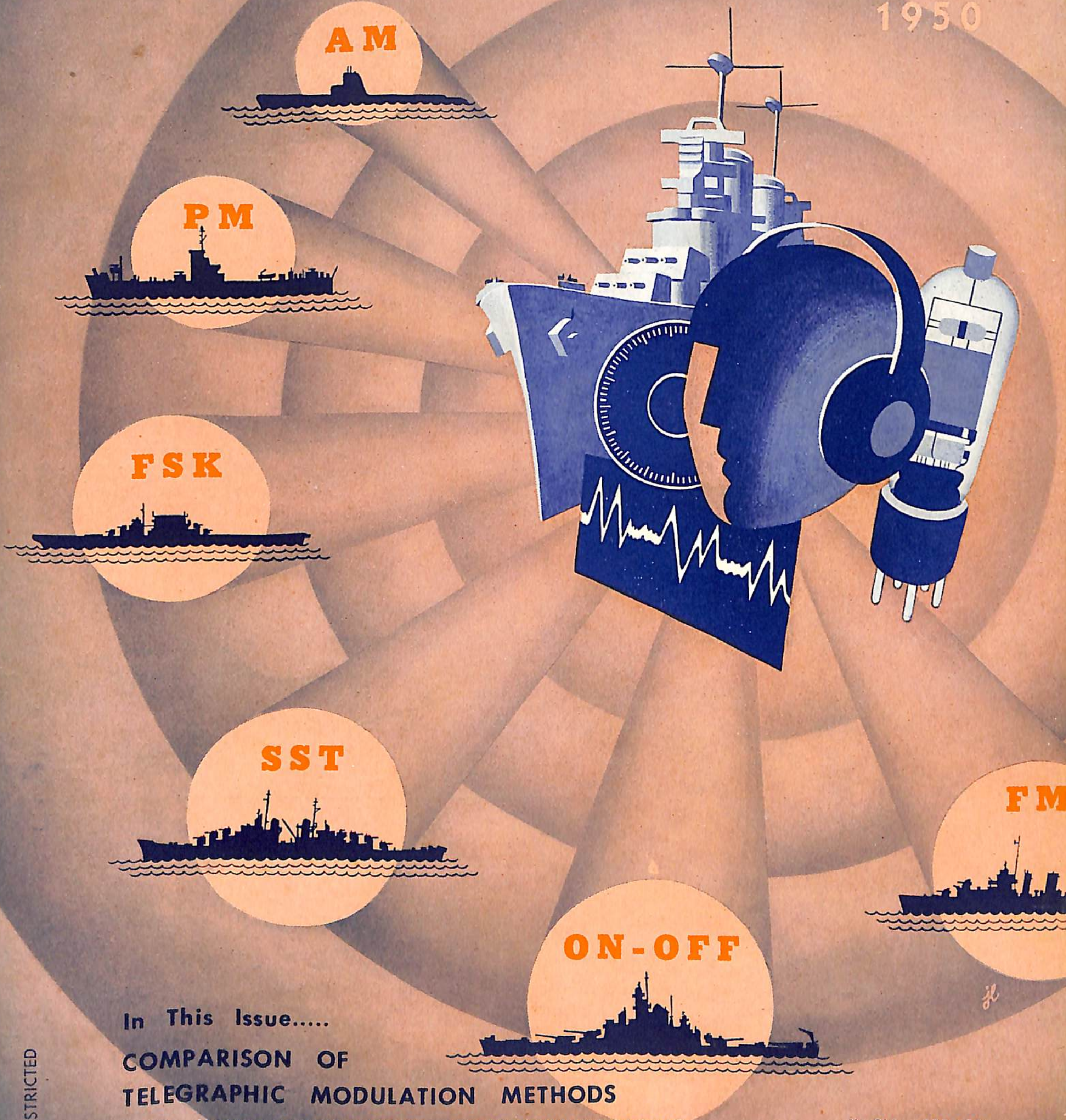

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Comparison of TELEGRAPHIC MODULATION METHODS *for Intra-Task-Force Communications*

by
H. G. Wolff
Systems Engineering Division
U.S. Navy Electronics Laboratory

Introduction

The general object of this work was to examine the comparative utilities of standard modulation methods for intra-task-force teletype communication up to a range of 200 miles. The problem arose from a desire of the Bureau of Ships to find a more practicable method than frequency-shift keying (FSK) for this kind of automatic communication. The Bureau's dissatisfaction with FSK was expressed as follows: "It is desired to establish a more satisfactory method of operating on single frequency radio teletype networks that that now afforded by FSK. Network operation of FSK on non-crystal controlled transmitters and receivers is not practical. The difficulty of keeping one receiver aligned with one transmitter is multiplied many fold when a multiplicity of transmitters and receivers is employed." With FSK, the normal frequency shift of 850 cycles and the necessity to tune the receiver so that the shift occurs at the proper point on the converter discriminator characteristic make it difficult to maintain the tuning of even one receiver.

Theoretical considerations indicated that two-tone frequency modulation would provide ease of tuning and have several other advantages. Particular attention was therefore given to the practical development of this method.

In comparing the relative merits of communication systems, the basic criteria, listed below, have to be considered.

1—The channel width should be narrow so that, of the limited available frequency range, the portion used will be as small as possible.

2—The ratio of "intelligence power" to "total power" should be a maximum.

3—The rate of transmission of information, or for telegraph systems the keying speed, should be as high as possible.

4—The equipment should be simple and easily operated.

5—The equipment should be readily available and of low cost.

In addition, the system should be able to counteract the various unfavorable conditions which may occur in the terminal apparatus and in the transmission medium. These unfavorable conditions include extraneous noise, other interference, and fortuitous variations of received amplitude, frequency, and phase.

For intra-task-force communication, telegraphic modulation methods must be practicable at the frequencies (2 to 4 Mc) used in communication up to 200-mile range over sea water. This restriction of range and frequency largely eliminates fading or variation in received amplitude, since propagation is by ground wave; only at sunrise and sunset will difficulty ordinarily be experienced.

The following modulation methods are treated here with respect to their suitability for radio telegraph or teletype service:

1—amplitude modulation, using tone modulation,

2—single-sideband modulation, using tone modulation,

3—frequency modulation, using tone modulation,

4—phase modulation, using tone modulation,
5—ON-OFF keying, and
6—frequency-shift keying.

Each of these methods was theoretically evaluated. The theoretical results were tested by field and laboratory work, which also provided information on the practical aspects of equipment development.

Comparison of Modulation Methods

Amplitude Modulation

In amplitude modulation, even at 100 percent modulation, there remains in the carrier two-thirds of the total available power. This residual power in the carrier does not transmit intelligence, and is wasted.

Equipment is readily available for this method of modulation. However, an additional factor enters when a specific transmitter is considered. Since the peak power level at which the output stage operates is limited by the flashover voltages of circuit components, the average carrier power under full modulation is one-fourth of that which the output tube is capable of delivering in normal Class C amplification. This is the case for most Navy shipboard transmitters, and therefore only one-eighth of the carrier power capabilities of the transmitters will be available for transmission of the intelligence.

A favorable aspect of amplitude modulation is the small bandwidth required. If the keying wave is shaped so that high-order transients are not present, the bandwidth will be dependent mainly upon the modulation frequency employed.

Two-tone amplitude modulation employing separate tones for mark and space is more effective than transmission of a single tone during the mark condition only. This is because the effects of noise may be reduced by incorporating audio discriminators and other balancing systems in the converter equipment, permitting a signal-to-noise ratio lower than is necessary for single-tone operation.

With any method employing tones for modulation, a severe limitation of keying speed is imposed. For example, in teletype operation there must be a sufficient number of audio oscillations in each mark or space to permit its reconstruction at the receiver converter unit. The audio filter characteristics must be such that the rise and decay times of the audio tones will not occupy too great a fraction of the mark or space length, so that bias and end distortion will be within acceptable limits. Thus, keying speed will be limited, and, with this or any other type of modulation employing tones, the limitation must be weighed when judging the relative merits of the method.

Amplitude modulation permits facility of operation, and there is no difficulty in tuning. Signals are easily recognized, and receiver bandwidths are sufficiently broad so that minimum operator attention is required.

Single-Sideband Transmission

Single-sideband transmission is a variation of amplitude modulation. Since both the upper and lower sidebands carry identical intelligence, one sideband is redundant. By transmitting only one sideband and by suppressing the carrier, two highly desirable effects are realized. First, as noted before, in ordinary amplitude modulation the power of one sideband is only one-fourth of the carrier power at 100 percent modulation. In single-sideband transmission, on the other hand, the entire carrier power can be applied to the one sideband being used, achieving a power gain of 6 db. Furthermore, single-sideband transmission reduces the bandwidth requirements of the receiver by one-half, with a consequent signal-to-noise gain of 3 db. The over-all theoretical gain compared with normal amplitude modulation is thus 9 db, and tests indicate this to be borne out in practice.

Consider the energy transmitted in single-sideband modulation when two audio tones are employed. For single-channel telegraphic or teletype communications, the two audio tones are transmitted alternately, one representing mark and the other space. This results in two bands of radio frequency energy. As the tones alternate, there is a frequency shift in the transmitted energy. If the frequency difference between the two audio tones used in single-sideband modulation equals the carrier shift used for frequency-shift keying, the results given by the two methods are indistinguishable. Thus it can be seen that single-sideband modulation offers no advantage over a frequency-shift method in this application.

A major disadvantage of the single-sideband system, which has prevented its general use, is that the equipment involved is more complicated than that required for any other method of modulation here considered. Recently developed techniques may simplify the equipment and make the single-sideband method more attractive from the practical point of view.

Frequency Modulation

In frequency modulation the amplitude of the modulated wave is the same as that of the carrier, and intelligence is conveyed by varying the instantaneous frequency about a central point by an amount commensurate with the amplitude of the modulating signal. The rate of variation is commensurate with the frequency of the modulating signal. For simplicity, considering sinusoidal modulation, the instantaneous amplitude of the transmitted wave may be expressed as a series with the terms of the series representing the carrier and separate sidebands generated. The first term represents the unmodulated carrier, which carries no intelligence; successive terms represent the sidebands. Depending upon the value of the index of modulation, the amplitude of each sideband can be determined.

The analysis is illustrated by a set of curves in Terman's *Handbook,* page 579, and by the spectra depicted on page 581. For any index of modulation larger than 0.5, second- and higher-order sidebands, in addition to those of the first order, assume importance when bandwidth is being considered.

On the other band, only the power in the sidebands conveys intelligence. Thus, to obtain the maximum signal-to-noise ratio, a modulation index must be used which allows maximum power to be radiated in the sidebands. By use of a table of Bessel Functions, the first term of the series, which represents the unmodulated carrier, can be plotted as a function of the index of modulation, and it can be shown that this term, representing carrier power, equals zero for several values of the modulation index. A choice of modulation index can therefore be made so that all the available power is used for intelligence-bearing radiation. Full power is available from the transmitter under all conditions, though maximum intelligence-transmitting efficiency is attained only when the first term of the series is zero.

For most efficient operation, the index of modulation must be maintained constant over the modulation frequency range. In order to maintain a constant value of the modulation index, the variation of the radio frequency from the mean frequency must be proportional to the modulating frequency. This necessitates a pre-emphasis arrangement in the modulation circuit. Keeping the modulation index constant without regard to the modulating frequency means that operation will be under the conditions governing phase modulation. Thus, with a given modulating voltage, the bandwidth required will be proportional to the modulating frequency.

Phase Modulation

In phase modulation, intelligence is transmitted by varying the phase of the radio frequency wave. The the equation for phase modulation is the same as the equation for frequency modulation, except for the term indicating initial phase angle, and for the modulation index, which is defined differently. The modulation index is constant and is the phase displacement at the peak of the modulation cycle. The frequency deviates from the mean by an amount proportional to the modulating frequency.

Under these conditions the sidebands will be displaced from the carrier by an amount dependent upon the modulating frequency. Furthermore, with a given index of modulation, the total bandwidth required will also depend upon the modulating frequency. For these reasons it is desirable to use as low a modulating frequency as practicable.

At present, equipment is not available for phase or frequency modulation methods. However, with a minimum of changes, equipment which is available can be adapted to these methods. These modifications and the other changes to standard equipments necessary for this research, appear in the section of this article headed "Equipment Development".

The comments with respect to facility of operation, previously noted under amplitude modulation, apply to these methods also, namely, that there is no difficulty in tuning, that signals are easily recognized, and that receiver bandwidths are sufficiently broad so that minimum operator attention is required.

In phase and frequency modulation, the employment of limiters and of a discriminator type of detector gives the receiver freedom from the effects of impulse noise. This is particularly advantageous.

ON-OFF Keying

ON-OFF keying is a special form of amplitude modulation. The modulating function in the equation for amplitude modulation may be resolved by Fourier analysis into sinusoidal and cosinusoidal components which show that upper and lower sidebands are present in addition to the carrier. These are displaced from the carrier frequency by an amount equal to the frequencies of the modulating-function components.

For the special case of ON-OFF keying, the modulation factor, is equal to unity, and the modulation function represents a square wave for a keying condition of 50 percent ON and 50 percent OFF. The modulation envelope, assuming a perfect square wave, can be expressed as a Fourier series, with components theoretically extending to infinity as harmonics of the fundamental repetition rate of the square wave.

The Radio Corporation of America has made a study of bandwidth requirements for various keying methods. Their theoretical work indicates that for a square keying wave with a repetition rate of 40 per second, series of sidebands exist on each side of the carrier frequency at 40-cycle intervals. The sidebands progressively diminish in amplitude, until at about 1300 cycles from the carrier, the sideband power levels are some 40 db below carrier level.

Shaping of the keying wave to reduce the frequency bandwidth required in ON-OFF keying may be effectively utilized only by considerable alteration of the usual keying methods, as the nonlinearity of the Class C output amplifier stage ordinarily employed re-introduces high-order sidebands.

Spectral resolution of the frequency band used in ON-OFF keying indicates a width to the 40-db down point of 1100 cycles each side of the carrier. This bandwidth is smaller than the theoretical value because of the finite time required for the build-up and decay of the radio frequency energy in the transmitter output and antenna circuits. This latter factor in some instances seriously limits the keying speeds permissible, especially at frequencies in the region of 15 to 30 kc where antenna Q's are high.

The ON-OFF method of modulation has certain distinct advantages. For example, narrow-band radio frequency and audio frequency filters can be employed in the receiving equipment to reduce the noise susceptibility and allow the signal-to-noise ratio requirement to be met. Another and main advantage is the availability of equipment. Ordinarily, no additional transmitting equipment is required, while the receiving system needs only the simplest audio frequency converter and a standard communications receiver. The converter can be made by the average radio technician from parts ordinarily available at naval radio facilities. In emergencies, or when other equipment is not available, this method of keying is therefore useful.

The main disadvantage of ON-OFF modulation is its inability to accept variations in received amplitude. Since the carrier is not continuous, the automatic volume control in the receiving equipment cannot be utilized. For automatic communication it is therefore only suitable for conditions involving constant signal strength, such as ground wave propagation over relatively short distances.

Apart from attention required to control the level of the received signal, the method presents no special difficulty in operation. However, if selective audio filters are employed, to minimize interference from noise and unwanted signals, very close tuning tolerances will be imposed, and operators will encounter difficulty in maintaining receiver tuning.

It should be noted that since ON-OFF keying is basically a form of amplitude modulation, the maximum power in the intelligence-bearing sidebands is only 50 percent of the available carrier power.

Frequency-Shift Keying

Frequency-shift keying, in contrast with ON-OFF keying, may be thought of as a form of frequency modulation. With a 23-cycle teletype keying wave and an 850-cycle shift in frequency, a modulation index of over 35 results. This makes the unmodulated carrier power negligible, and all the transmitter power goes into the intelligence-bearing sidebands. Therefore, in transmission, there is a 3-db power gain with FSK as compared with ON-OFF keying.

The principal advantage of FSK is its ability to receive signals under conditions of rapid and extreme variation in amplitude. This results in greater stability and lower distortion than in the ON-OFF system. In addition, techniques involved in the recovery of the mark and space signals permit a reduction of carrier power, since the signal-to-noise requirements are not so stringent.

Proper shaping of the keying wave can be more easily employed than in the case of ON-OFF keying to limit the amplitude and number of the sidebands. The keying wave shape is preserved in the Class C stages of a transmitter.

With a 40-cycle keying wave and using a 2-section, 300-cycle, lowpass filter, the bandwidth to the 40-db down point is about 600 cycles each side of the carrier frequency, or one-half the bandwidth requirement for ON-OFF keying. The reduction in bandwidth required becomes more marked as the frequency of the keying wave is increased.

The characteristics of the frequency-shift converters at the receiving end affect the over-all performance of the frequency-shift method. The Navy has several types of receiver converters, three of which, the FRF, the FRA, and the FRE, have been previously investigated at the Laboratory. For these three, the signal-to-noise ratio requirement was best in the case of the FRF converter, mainly because of the narrow passband of its keying filters, which pass only the third harmonic of the 23-cycle keying rate.

The FRF converter, however, suffers the most from the main weakness of the frequency-shift method. This

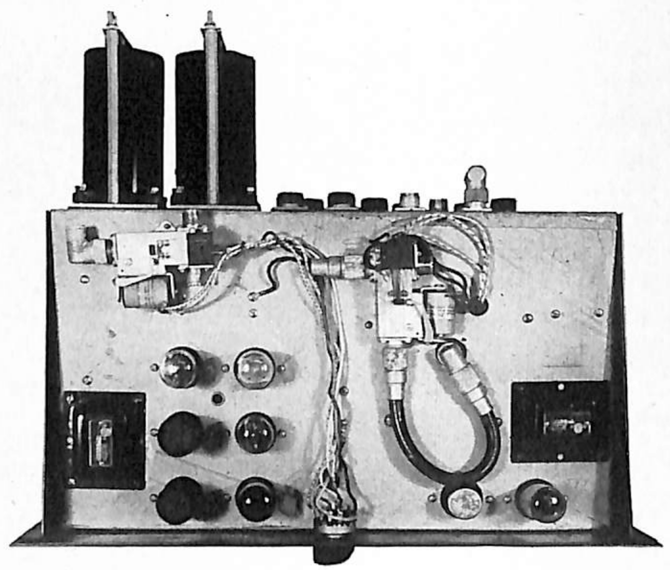


FIGURE 1—The switching unit.

weakness is most apparent when single-frequency network operation of radio teletype circuits is attempted. Under such conditions precise tuning, which is an FSK requirement, makes operation impracticable. The degree of precision required depends upon the selectivity of the discriminator of the specific receiver converter, particularly when non-crystal-controlled transmitters and receivers are employed.

On the other hand, this precise tuning requirement is no drawback to fixed stations using inherently frequency-stable, crystal-controlled transmitters, and crystal-controlled receivers. Where space, weight, and equipment-complication factors are relatively unimportant compared with reliability of communication, FSK is the best method of modulation so far considered.

The equipment for FSK is in general use, but is relatively complicated where full advantage is taken of its inherent capabilities.

This method, like FM, employs limiters and frequency-discriminating detectors and is thus unsusceptible to impulse noise.

Experimental Investigation

The purpose of the experimental work was to develop equipment for two-tone frequency modulation for radio teletype, as well as to compare the merits of the other methods being considered.

The premise upon which the work was based took into account the desirability of using as much standard equipment as feasible, and modifying it so that it could be used on FM. The emphasis was placed on FM although the use of two-tone AM would also alleviate tuning difficulty, because AM would necessitate the use of

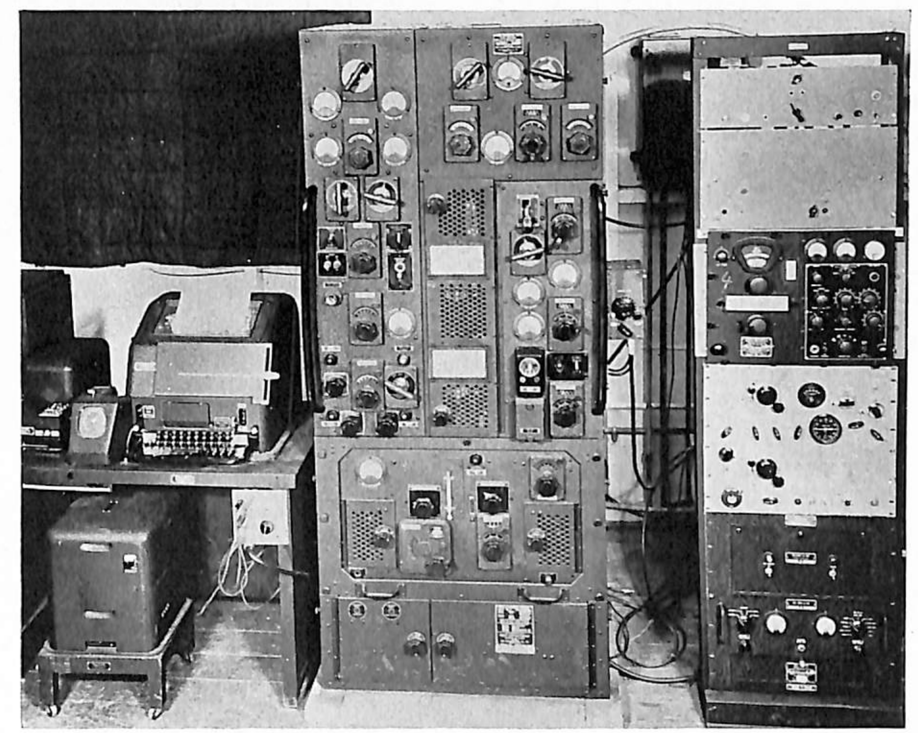


FIGURE 2—Over-all view of test equipment.

high-level modulators or require the sacrifice of available power if low-level modulation were used.

Assuming a 4-kc bandwidth in the RBB-2 receiver, it was necessary to determine the maximum audio modulation frequency permissible. The bandwidth is equal to $2nf$ where n is the highest order of significant sideband and f is the modulation frequency. It has been shown that at the first point of zero carrier power, the modulation factor is equal to 2.405, and sidebands are significant up to and including the third order.

Under these conditions 667 cycles represents the maximum permissible modulating frequency for this 4-kc bandwidth. However, there is presently being purchased certain standard Push-To-Type Radio Teletype (PTT-RATT) equipment which uses an upper (mark) frequency of 700 cycles. This will give a bandwidth requirement of 4.2 kc, which has been found satisfactory.

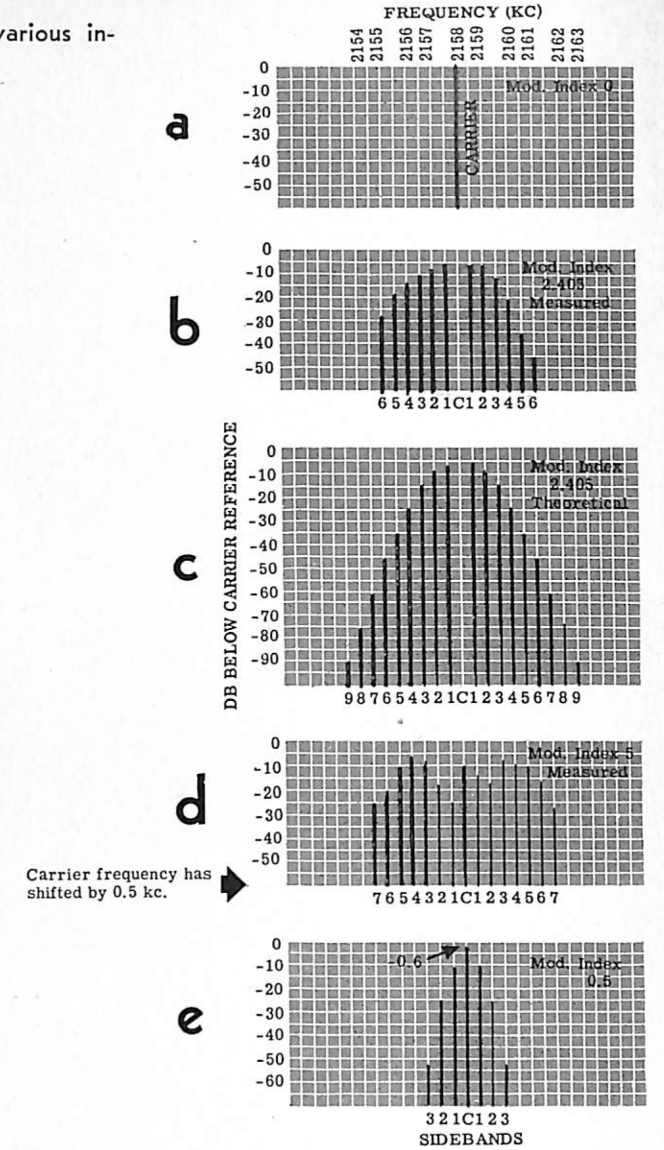
Inasmuch as the AN/SGC-1 PTT-RATT equipments were not available, it was necessary to develop experimental models suitable for the tests.

The receivers employed throughout these tests were RBB's, modified by the addition of discriminators. The switching unit shown in Figure 1 was developed and incorporated into the test equipment, so that choice of the method of modulation could be made with minimum delay. An over-all view of the test equipment is shown in Figure 2. A standard TBL transmitter and an RBB receiver, with some modifications, were used. An 85-foot broadbanded whip antenna was constructed and installed on the west side of the Laboratory site at Point Loma, and used for both transmitting and receiving. The antenna with its matched coupling unit was connected through some 800 feet of 50-ohm RG-18/U cable to the equipment.

Shipboard facilities included a similar transmitter feeding a 30-foot whip antenna. The receiver, switching, and terminal equipments were arranged identically with those in the Laboratory. A portable teletypewriter TG-26-A was used instead of the model 19. A frequency of 2158 kc and a maximum input power of 500 watts were used at each end of the communication circuit.

In order to run an operational test on the system, one set of equipment was installed on the Laboratory site. Over a 36-hour trial period, during which the ship proceeded to a point some 200 miles west of the Labora-

FIGURE 3—Relative sideband power for various indexes (500-cycle tone).



tory, comparative data was taken for the various methods of modulation.

The results anticipated on the basis of theoretical analysis were verified by the test data. Assuming an unmodulated carrier at a reference level of 0 db (Figure 3a), the actual transmitted sideband levels are indicated in Figure 3b. The values compare favorably with the theoretical sideband amplitudes, shown in Figure 3c. Sidebands more than 45 db below the unmodulated carrier level were not received above the ambient noise

The modulating voltage was increased until the modulation index was equal to 5, with the experimental results depicted in Figure 3d. The lack of symmetry was apparently caused by overdriving the reactance modulator in the FSA unit, with resultant nonlinearity of reactance with respect to modulating voltage.

During the tests it was determined that a usable teletype signal was available throughout the acceptance bandwidth of the receiver, and its quality of reception was dependent upon the signal-to-noise ratio at any given time. For example, when the signal level was 52 db and the noise level 30 db, a signal-to-noise ratio of 22 db resulted, and the dial spread over which teletype signals could be received was 15.6 kc. By reference to Figure 4, it can be seen that for a signal-to-noise ratio of 22db, the bandwidth of the RBB receiver is approximately 16 kc. This means that the operator has only to tune the receiver with sufficient precision so that signals are audible above the noise level, and satisfactory teletype copy will be provided.

In the original proposal for the use of FM, it was suggested that a small index of modulation might be employed. The experimental results as well as the theory indicate this to be possible. For one of the tests a modulation index of 0.5 was used. Satisfactory teletype service was afforded, though it was found that a considerable reduction of audio power from the receiver resulted. This is to be expected, and can be explained by reference to the sideband chart shown in Figure 3e, which illustrates the relative amplitudes of sidebands at a modulation index of 0.5. Roughly 87.5 percent of the total power is in the unmodulated carrier, and 12.5 percent is in the intelligence-bearing first-order sidebands. Higher-order sidebands have neglible power. It is apparent that the bandwidth required is essentially the same as for AM, and is 1.4 kc or twice the upper modulating frequency of 700 cycles.

The power efficiency compares with that of amplitude modulation only 50 percent modulated. For the 0.5 index the intelligence power is one-eighth that for a modulation index of 2.405, which represents a 9-db decrease in the signal-to-noise ratio. For the 200-mile test, using strong signals, the 9-db loss was not detrimental. In service, it may be desirable to operate with an index of 0.5 until noise levels become high. Then the index could be raised, increasing the signal-to-noise ratio by 9 db. The increase in bandwidth would have to be tolerated in such circumstances.

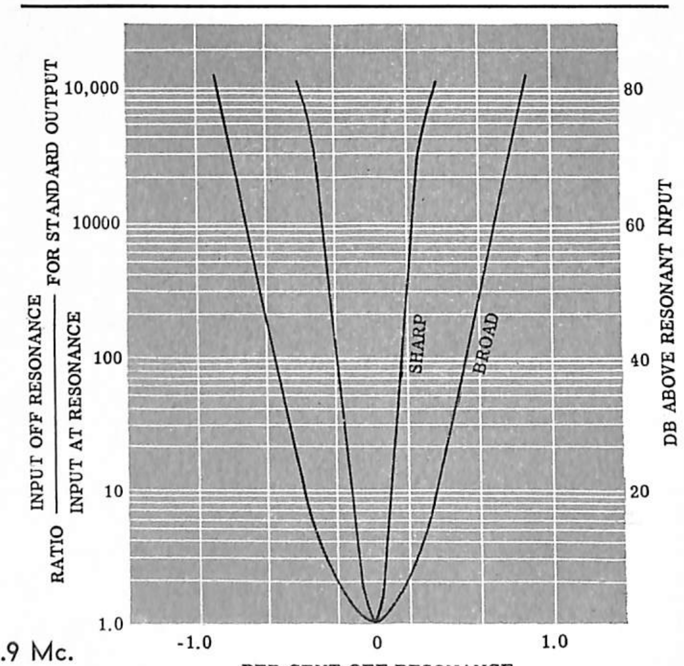


FIGURE 4—RBB receiver selectivity at 1.9 Mc.

It is desirable to point out an FM characteristic of special interest for this application. When an AM receiver is slightly detuned from the carrier, it will detect FM, particularly if the i-f bandpass is narrow, affording discriminator action for FM. Some audio distortion is introduced, but the PTT-RATT unit operates satisfactorily with considerable audio distortion from the receiver. Acceptable teletype service was obtained from the RBB-2 receiver under the following conditions: With the receiver detector set on AM and its selectivity control set on SHARP, the dial spread was 5.4 kc with 8 microvolts input. The separate FM discriminator was not required for this test. While it is not desirable to operate in this manner, in case of necessity an unmodified receiver could be used.

The sharpness of tuning required by FSK was readily apparent. The operable bandwidth as indicated by receiver tuning was 2.16 kc. Furthermore, extreme care had to be exercised in adjusting the FRF converter, and over a period of time the adjustments had to be realigned. The MARK HOLD control setting was very critical. Often, if it were set for a particular level to avoid keying the printer by random noise when no signal was being received, the printer would not operate when the FSK signal was received.

Under two conditions, FSK was advantageous. First, FSK signals were not nearly as much disturbed by voice interference as were AM or FM. This was due to the inherent characteristics of each system, as well as the selectivity afforded by the i-f and lowpass audio filters in the FRF converter. Secondly, these same narrowband characteristics provided favorable results under poor reception conditions when weak signals were received in the presence of noise.

The superiority of FSK to FM in these respects is shown by the following comparative results, obtained after tuning the equipment to optimum at high power. With the ship 200 miles away, satisfactory copy was received by hand typing with the FSK signal transmitted at a level of 6 watts. In the case of FM, in order for the PTT relays to operate, a power of 24 watts was necessary. With automatic keying, however, there was no appreciable difference in results for the two methods of modulation.

On the other hand, FM exhibited certain advantages over FSK. Most apparent was the ease of tuning at the receiver; in fact, it was difficult not to receive perfect copy. Whenever the signal could be heard by headphones, the printer operated without error. For standby operating conditions, two characteristics showed merit, namely: drift in the receiver over a period of time did not cause loss of contact, and random or impulse noise did not key the printer. A finite time of transmission of the space tone with 500-cycle modulation is required so that the receive relay in the PTT unit will be actuated and unlock the printer loop. This permits the printers to be set in the standby condition, with motors off. When the first character is received, the motors start. Using FSK, however, instantaneous noise impulses cause space signals to appear on the printer loop, and spurious characters print during standby conditions.

Many of the comments with respect to FM are also applicable to AM. The essential differences are those caused by AM's lower power-transmission capability, and by its narrower bandwidth.

In the case of ON-OFF operation, it was found that the TBL keying relay would not satisfactorily follow the teletype keying impulses. The marking pulses were too short to allow the printer to operate properly. Since the

TABLE 1. COMPARATIVE MERITS OF MODULATION METHODS

REQUIREMENT	METHOD OF MODULATION			
	ON-OFF	FSK	TWO-TONE AM	TWO-TONE FM-PM†
Acceptance of variations in received amplitude		xx	x	x
Acceptance of variations in frequency	x*		x	xx
Freedom from interference caused by extraneous signals	x*	xx		
Freedom from interference caused by noise		x		x
Minimum-bandwidth intelligence power	x	xx	x	
Peak power		x		x
Ease of operation	x*		xx	xx
Keying speed (60 words per minute)	xx	xx	x	x
Availability of equipment	xx	x		x

x indicates that the requirement is fulfilled.
xx indicates superior to other methods for the particular requirement.
* These characteristics are mutually exclusive. Employment of a sharp audio filter to minimize interference will preclude taking advantage of the other two favorable characteristics.
† The frequency and phase methods of modulation give essentially the same results.

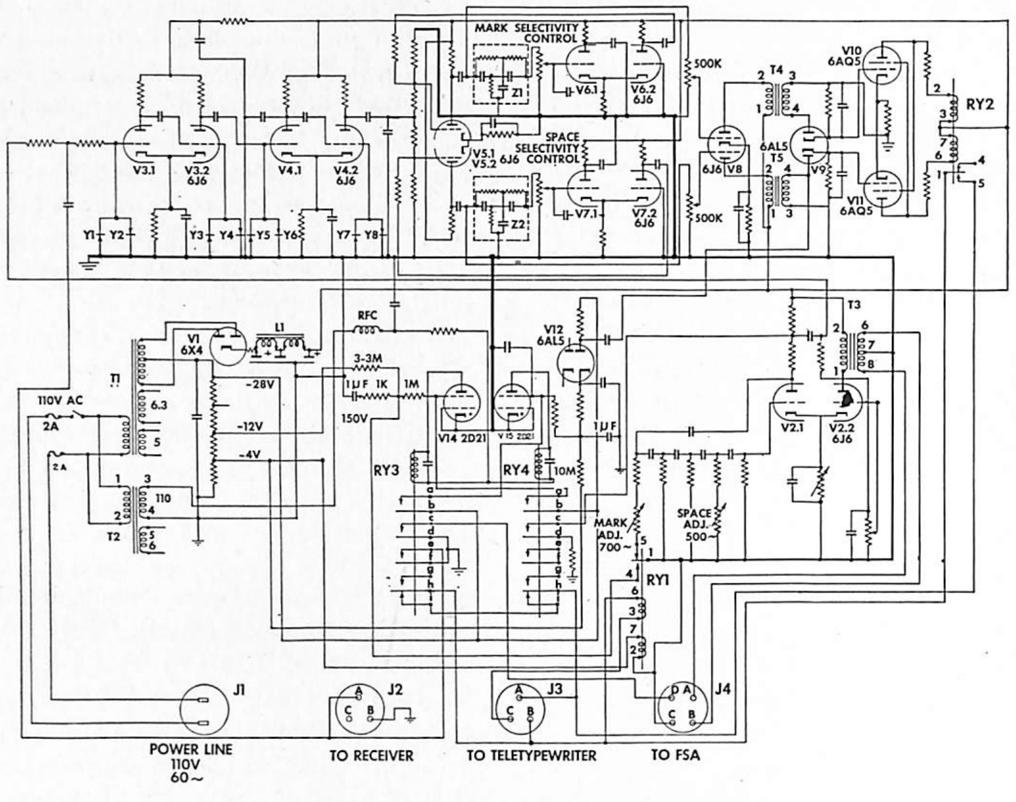


FIGURE 5—Schematic diagram of push-to-type radio telegraph terminal equipment.

importance of this method is limited, it was not investigated quantitatively.

Conclusions

The data are summarized in Table 1, in order to facilitate comparison of the various methods of modulation. The conclusions below, based on Table 1, are conditional upon the following assumptions: operation on teletype keying signals; two-tone single-channel operation on FM and AM; and electronic keying of transmitters as opposed to relays.

Frequency-shift keying is outstanding in several characteristics and satisfies most requirements. However, it does not accept variations in received-signal frequency and it does not provide ease of tuning. At fixed stations, where crystals may be employed, these disadvantages are minimized and the method is the best of those listed. As indicated in Table 1, all the methods fulfill the keying speed requirement of 60 words per minute; however, at higher speeds, FSK is most advantageous.

For shipboard operation in a fleet net, frequency modulation will be most satisfactory. Relatively simple modifications of equipment now available or under present procurement will permit the system to be used. However, like other methods depending upon audio tones to transmit telegraphic characters, FM is especially susceptible to interference caused by voice or music. Each time the interfering signal contains one of the two tones used for mark or space, an error may result in the typed copy.

Suitable equipment for amplitude modulation is not available in many naval facilities. High-level modulators are in most instances not aboard ships, while low-level modulation does not take advantage of the power capabilities of the transmitter.

ON-OFF keying has the over-all advantage of simplicity. It does, however, have the extreme disadvantage of inability to cope with variation in received amplitude. This precludes its employment for normal automatic communication. In emergencies, or when other equipment fails, it may become the best method of keying.

As a matter of general interest, it was found that voice transmission of communication quality was afforded by modulating the FSA keyer with a microphone and speech amplifier. This may find practical application in the fleet.

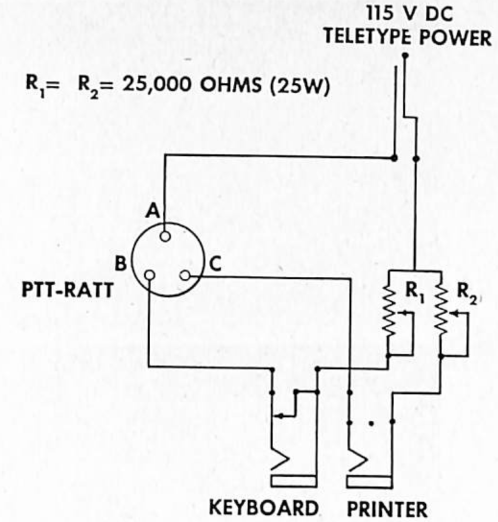


FIGURE 6—Teleprinter connections.

Recommendations

Pending development of a better method, two-tone frequency modulation should be established for short-distance shipboard network use.

Effort should be expended toward adaptation of single-sideband techniques and simplification of the necessary equipment.

Methods of modulation not covered by this report should be investigated to find whether they can be practically adapted for use in the high frequency band.

Equipment Development

In order to test the frequency modulation method, equipment models were developed in the Laboratory and modifications were made to existing equipments. As a result, units were constructed of simpler design than types previously developed under contract.

The principal economy was made in the filter circuits. In place of conventional iterative filters, it was decided to use selective feedback amplifiers. It was found that a reasonably simple circuit could be used, the amplifier having a weight of 5 or 6 ounces instead of approximately 8 pounds for the conventional type of filter.

The principles involved are presented in the literature. A modification of the familiar, parallel-T, resistance-capacitance, frequency-selective network was used. The circuits are explained in the succeeding discussion of the laboratory model PTT-RATT.

The schematic diagram shown in Figure 5 indicates the circuits concerned. The power supply is conventional, with one exception, namely, that the center tap of the high voltage winding of the transformer, T1, is connected through a series of resistors to ground. These resistors provide suitable bias for the control and relay circuits. The 6X4 rectifier, V1, is fed to a choke input circuit, and provides 225 volts at 70 milliamperes. An additional transformer, T2, provides power for the thyratron control circuits. Choke and capacitor filters are necessary to eliminate r-f noise generated by the thyratrons.

One winding of the transmitting relay, RY1, is biased with 30 ma from the —4 volt terminal. The other winding of RY1 is in the KEYBOARD loop of the teletype machine. Figure 6 indicates how the teletype machine is connected, and how the KEYBOARD and PRINTER loops are separated.

The transmitting oscillator, V2.1, utilizes a phase-shift network for frequency determination. The important feature of this oscillator is its ability to shift from 700 cycles (mark) to 500 cycles (space) smoothly and without change of phase. This is done by keying a circuit that does not store energy. The keying relay, RY1, places the mark resistors in the phase-shift network, decreasing the time constant of the RC combination, thus increasing the oscillation frequency. An oscilloscope pic-

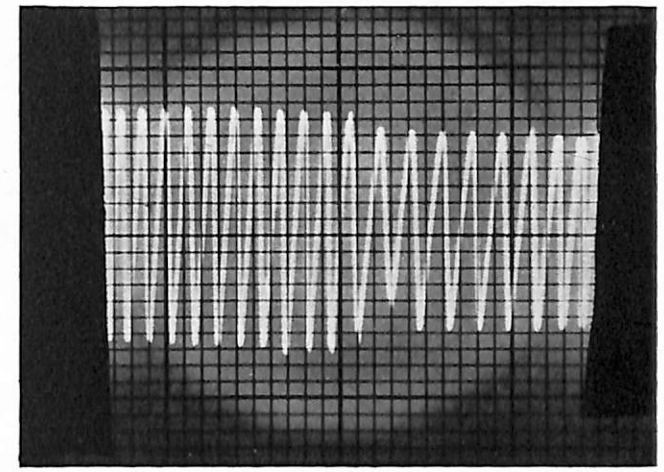


FIGURE 7—Representation of oscillator transition from 700 to 500 cycles.

ture of the transition point, illustrated in Figure 7, shows a smooth frequency shift without change in phase.

In order to control the percentage modulation for A3 transmission or to control the index of modulation for FM, a gain control is placed in the audio amplifier stage, V2.2. The output transformer feeds the modulating voltage to the line.

The input network to the receiving portion of the terminal equipment consists of two sections. The first section is coupled to the radio receiver, and thus receives the signals from the distant station. The second section is coupled to the local two-tone oscillator for the purpose of monitoring local transmission. Thus, when the local keyboard is actuated, a signal from the local oscillator is introduced through a high resistance to the input circuit, in turn actuating the receiving relay and thus the printer itself.

The first four stages of amplification are used as limiters as well as amplifiers. The limiters employed are 1N34 crystal diodes, placed back to back. When signals of very low voltage level are impressed on them, they present a high impedance, and as the level of the voltage increases, their impedance decreases. Over a series of amplification stages this effect is cumulative, and results in substantially constant output, within 3 db, for an input variation of 54 db. Normally, an audio level of 4 volts is provided by the receiver.

The equipment differs essentially from existing types, chiefly in the design of the selective amplifiers. The twin-triode tube, V5, is the selective amplifier. V5.1 is used for the 500-cycle tone. The grid of each section is fed through a network of three resistors to permit isolation of the feedback circuit separating it from the normal coupling to the preceding amplifier, V4.2. Networks, Z1 and Z2, are conventional twin-T resistance-capacitance combinations, tuned to reject 700 and 500 cycles, respectively. For example, the output of Z1 contains all frequencies except 700 cycles, but is some 20 db below the input to the network. In order to have a larger equivalent Q, and consequent greater selectivity, it is necessary to amplify and also to preserve the phase of Z1's output. To this end, a cathode follower, V6.1, and a cathode-coupled grounded-grid amplifier, V6.2, provide 20 db gain for the feedback voltage. This latter voltage is returned to the grid network of V5.1. Thus, at all frequencies other than 700 cycles, there exists a large negative feedback, with consequent suppression of amplification by this tube. At 700 cycles, Z1's output is greatly attenuated; there is no feedback, and V5.1 amplifies. The bandwidth or selectivity of the amplifier depends on the amount of feedback. A "mark selectivity control" potentiometer determines the gain of the feedback tube V6.

There is an optimum setting of the selectivity control. If Q is too low, there will be insufficient noise rejection at low input signal-to-noise ratios. If Q is too high, the narrow band causes a rounding of the keying pulses, and the teleprinter will not operate over maximum range. Figures 8a through 8e illustrate the effect produced by increasing Q. A pair of curves showing the selective amplifier characteristics is given in Figure 9. The Q's for these curves were optimal in a particular instance for rejection of noise and for shape of the keying envelope. In this application where keying envelopes are involved, theoretical considerations preclude the use of as high a Q as Figure 9 would indicate. The reason for the good performance of this circuit is obscure and further investigation would be necessary to elucidate it.

The individual mark and space signals, after selective amplification, are balanced in level by means of the 500,000-ohm potentiometers; they are further amplified individually by V8, permitting the proper voltages to appear at the output transformers, T4 and T5. An illustration of the audio signal voltage across T4 is shown in Figure 10a, in which the teletype character exemplified is "Y" (start—mark—space—mark—space—mark—stop). The dual diode, V9, rectifies the audio frequency, and provides a direct current envelope in accordance with the keying impulses. The time constant of the RC network in the cathode circuit is chosen so as to integrate the keying impulses for 10 milliseconds. The rectified impulses, having a relatively smooth envelope, are shown in Figure 10b. These d-c impulses are impressed on the grids of the keying tubes, V10 and V11, the screen grids of which are cross-connected to the plates of the opposite tube. This provides a flip-flop action, resulting in square waves of plate current as shown in Figure 10c. The end result is positive action at the keying relay, RY2, which, of course, itself provides some degree of integration. The three integrating effects, namely those of the RC rectifier network, the flip-flop power amplifier action, and the relay balance, all tend to minimize errors in the printed copy in the presence of noise.

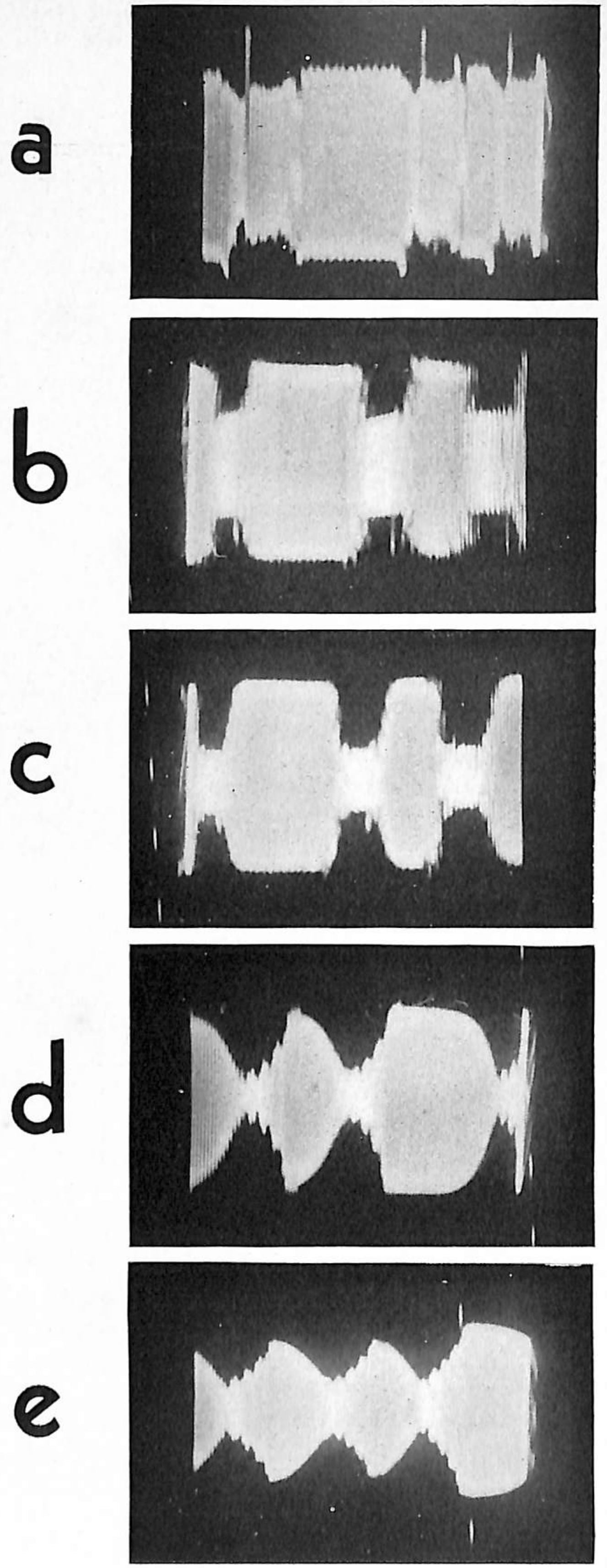


FIGURE 8—Keying pulses showing effect of increasing Q.

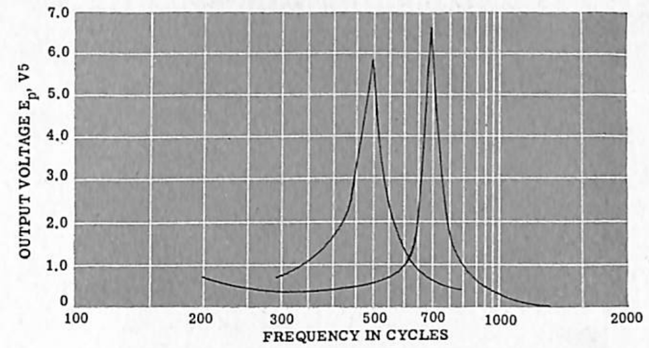


FIGURE 9—Filter characteristics of PTT-RATT.

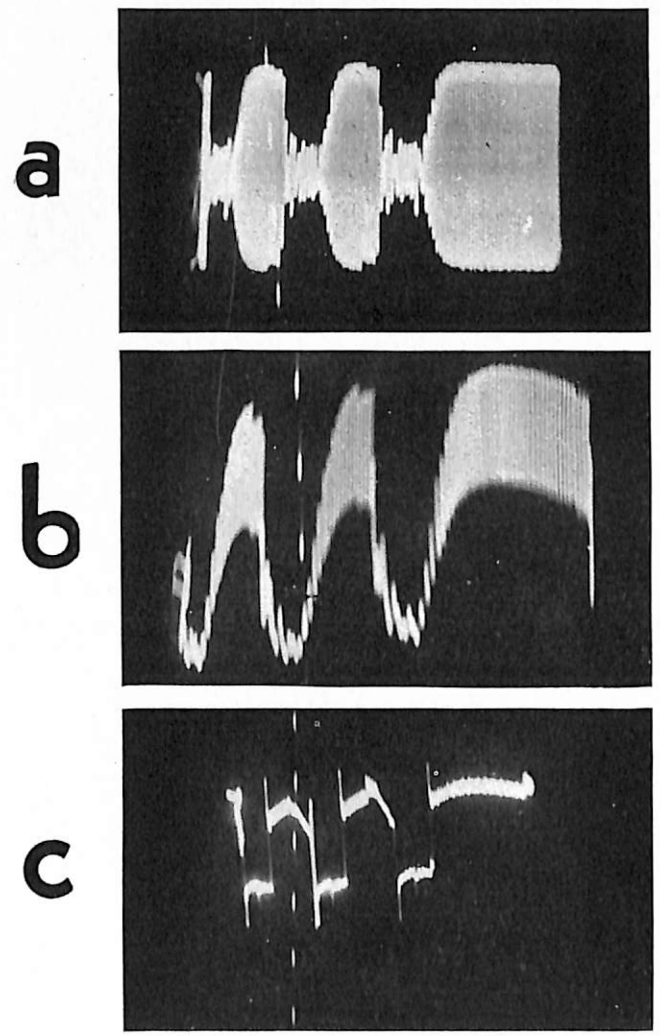


FIGURE 10

(a) Keying impulses at audio output transformer T–4.
(b) Diode voltage produced by rectifying keying impulses.
(c) Flip-flop current in power tubes.

Two control circuits provide the push-to-type feature. The interruption of teletype-keyboard line current caused by the actuation of a key operates transmitting relay, RY1. This momentarily grounds the space contact, 4, grounding the grid of V14, the thyratron which actuates RY3. The RC time-delay circuit, consisting of a 3.3-megohm resistor and a 1-microfarad capacitor, allows the thyratron to remain conductive for approximately 4 seconds after the momentary contact at RY1, before the rising bias cuts V14 off. A 1000-ohm resistor in series with the 1-microfarad capacitor limits the maximum current to a safe value for the contacts of RY1. RY3 performs several functions: it locks out the receiving relay, RY4, by application of bias to V15; it grounds the transmitter control circuit, turning on the transmitter; it grounds the input from the receiver, preventing possible interference with local monitor copy; it opens contacts "h" and "i", removing the short circuit on the printer loop.

In order to receive a transmission, RY4 has to be actuated. From the distant station, a space tone is received, causing a 500-cycle voltage to appear at terminal 4 of transformer T5. A portion of the 500-cycle power is rectified by V12, producing a positive voltage at its cathode, which counteracts the normal negative bias present on the grid of V15, causing V15 to conduct and closing RY4. With removal of the 500-cycle tone, the bias builds up through the time-delay RC circuit consisting of the 10-megohm resistor and 1 microfarad capacitor; after approximately 4 seconds V15 is cut off, and RY4 opens.

Functions performed by RY4 in the "receiving" condition are: locking out relay RY3 by application of bias to the grid of V14; cutting off the tone oscillator amplifier tube by application of load to the plate of V2.1; opening contacts "h" and "i," thus removing the short circuit across the printer loop.

The short circuit across the printer loop during the

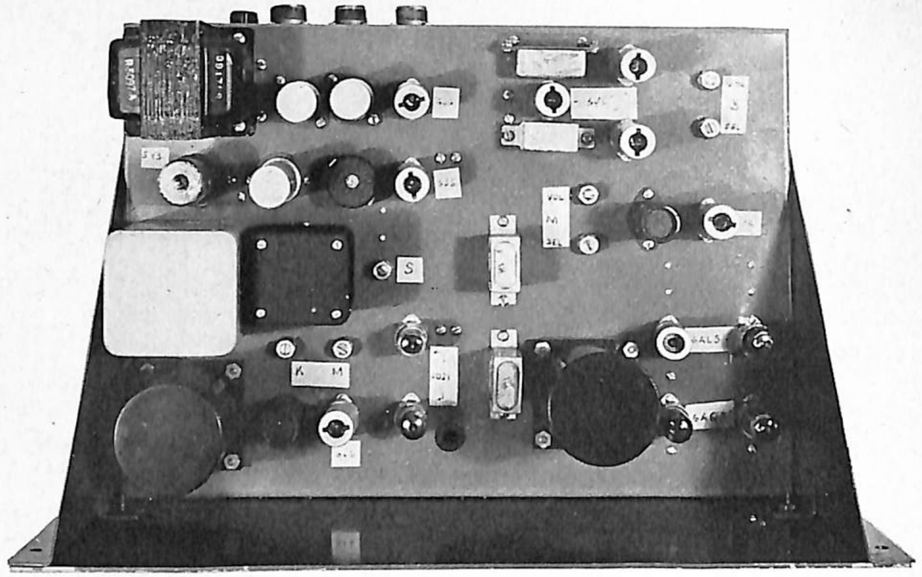


FIGURE 11—Top view of PTT-RATT unit constructed at NEL.

standby condition is desirable in order to prevent spurious printing in the presence of high levels of noise when no signal is being received. Normally, the mark tone from the local oscillator, feeding the input of the receiving circuit, provides a "mark return" characteristic. The short circuit is an additional safeguard. The PTT unit, as constructed in the Laboratory, is shown in Figure 11.

In order to permit operation on two-tone FM with existing equipments, certain modifications to them are required. Figure 12 illustrates the changes to an RBB–2 receiver, to which a cathode follower has been added. This circuit was found superior to the CN–10563 coupling kit used with the FRA frequency-shift converter. The low-impedance output feeds a National NFM–73 adaptor, modified in accordance with Figure 13 to permit its use with the RBB–2 receiver. This particular adaptor was chosen since it was readily available, thus simplifying later procurement. The noise limiter switch, S303, is removed and replaced with a three-position switch, the third position of which is labed FM.

Modifications to the FSA frequency-shift keyer are illustrated in Figure 14. The choice of FSK or FM is made available by the addition of a switch replacing S107. Relay RY5 transfers the grids of the modulator tubes from the normal FSK circuit to the audio input when FM is selected. Operation of transmitting relay, RY3, in the PTT-RATT unit, causes RY6 to close, completing the plate supply in the FSA and energizing the transmitter.

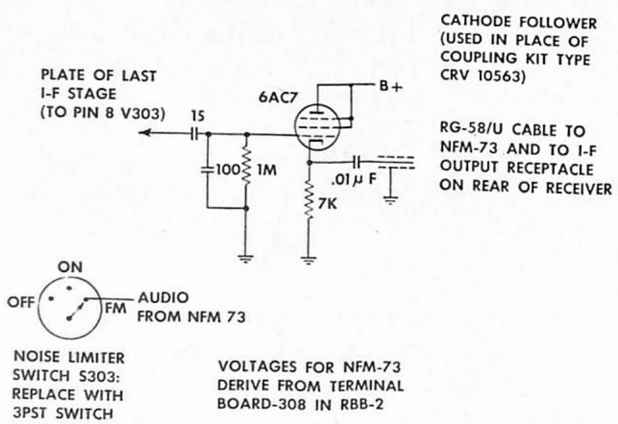


FIGURE 12—RBB–2 receiver modifications.

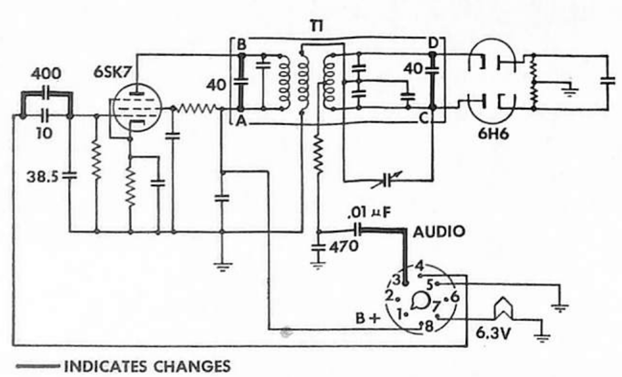


FIGURE 13—NFM–73 discriminator modifications.

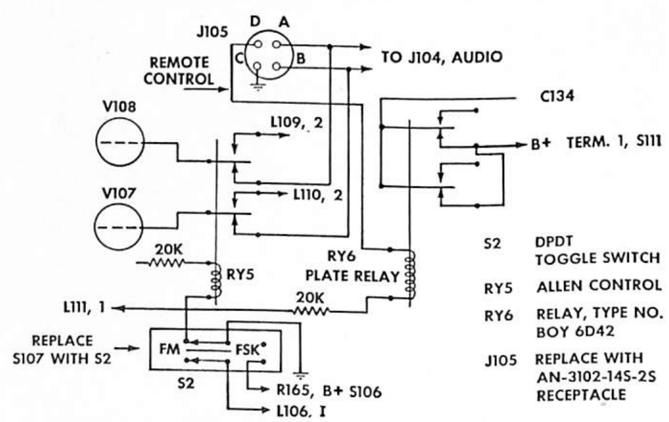


FIGURE 14—Modifications to FSA frequency-shift keyer (switches are in FM position and relays are in transmitting condition).

Letters to the Editor

Introducing a new, and it is sincerely hoped, a permanent feature of your magazine—Electron. This new feature is the answer to numerous suggestions and requests from fleet and shore personnel for a medium of presenting their individual problems, gripes and questions on electronics matters and obtaining answers to such queries. This section is not to be confused with the FORUM which has been a regular part of the Electron since its inception in 1945. The continuance of this new feature depends entirely on you—the personnel in the field—since we must first receive correspondence from the field before we can search out the answers and print them. As a matter of convenience, it is suggested you write directly to:

The Editor
BuShips Electron
Code 993
Bureau of Ships
Navy Department
Washington 25, D. C.

The following are typical of the type of letters received to date for inclusion in this column:

Editor,
BuShips Electron
Sir:

In reference to Paragraph 4, Column 2, Page 22, July 1950 Electron, concerning maintenance of duplexers, would you please answer several questions that this article has raised.

1—What is considered a suitable "brightwork" polish.

2—How is the polish to be removed? With some fluid other than carbon-tetrachloride, or by a clean rag and elbow grease?

T.R.A.

1—General Stores Materials Stock Number 51–P–1177 is recommended for cleaning either silver-plated or brass duplexers or waveguide fittings.

2—Your elbows are due for some exercise—apply with a cloth and remove with a clean cloth being careful to leave none of the dry polish on the surface.

Editor.

Editor,
BuShips Electron
Sir:

An article in the August 1949 Electron entitled "New Model TDZ Tuning Procedure" stated that a film on this subject would be available on or about 1 September. We have on hand the Supplement No. 27 of the CEMB which contains the new tuning procedure, but several details are not clear to us. Can you advise us how and where to obtain this film. We are having some difficulty in tuning our TDZ and would like to obtain this film.

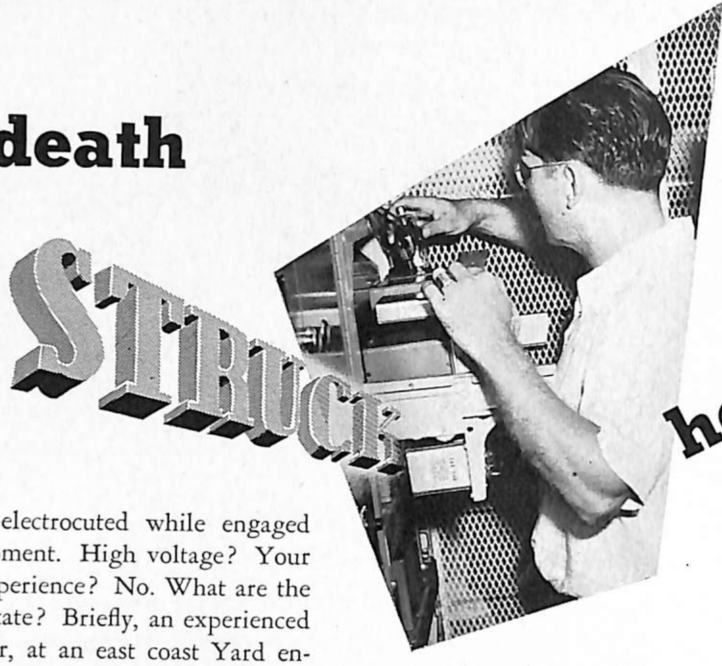
F.H.Y, ET1 USN

A copy of this film may be obtained from the nearest District Training Aids Officer. There may be a waiting list so you should apply for the film as soon as possible.

In the meantime we would like to hear about the details which are not clear and also about any other troubles you might be having with the new tuning procedure.

Editor.

death STRUCK here



Another man has been electrocuted while engaged in servicing electronic equipment. High voltage? Your first thought. No. Little experience? No. What are the facts and what do they indicate? Briefly, an experienced associate electronics engineer, at an east coast Yard engaged in servicing a Model QGA equipment on board the destroyer *USS Goodrich* made accidental contact with terminal 187 on the tilt control stack and received 250 volts a.c. from left chest to left foot.

The opinion rendered after investigation included the following statements:

1—Death occurred due to a temporary lapse of attentive good judgment on his part.

2—His lapse of attentive good judgment was that while turning his head to read the instruction manual he failed to consider his physical position with relation to the voltages exposed on the unit on which he was working, while at the time primary power was being supplied to the unit and that he was hot, perspiring and working in cramped quarters.

3—That the fatal electric contact was made as he turned back to face the equipment from reading the instruction manual.

4—That the proximate cause of death was electric shock of 250 volts a.c. encountered from terminal 187 to ground.

5—That a drilled safety cover over this and similar terminal blocks would act as a preventor for unintentional contact casualties of this type without hindering voltage or resistance readings for the terminals in question during equipment check outs.

6—That rubber or other types of safety mats should be examined and tested periodically to insure retention of full insulating properties.

7—That all persons having reason to work on electric or electronic equipment should be diligently informed of the hazards in working on the so-called lower potentials.

In reviewing the Findings of Facts, we find that the usual unfavorable conditions *normally encountered on shipboard* were present, i.e.:

1—Small crowded spaces.

2—Profuse perspiration—body and clothing wet.

Additionally the findings indicate:

1—Personnel knew potentials existed at this terminal block when power was supplied. That personnel working with this same equipment in previous days had received shocks from the same terminal panel.

2—That personnel who received the shocks considered them incidental hazards to their craft.

3—The terminal strip on which 153 and 187 are located is open to the front when chassis is tilted for servicing and that it had no protective cover.

4—Subsequent voltage measurements were 250 volts a.c. between terminals and between terminal 187 and ground which normally should carry a nominal voltage of 115 volts.

5—That 115 volts, the nominal voltage, is a hazardous voltage.

6—The instruction book had been placed in back of and to the right of man while he was in the servicing position in front of the equipment.

7—That he diverted his attention from the equipment on which he was working, to read his instruction manual while power was still supplied to the chassis under test.

Get these points fixed in your mind based on testimony given:

1—A nominal 115-volt circuit is dangerous.

2—Three persons indicated in testimony that they had received shocks from the equipment before.

3—"The way he was working he had to continuously check the circuit to see what he was doing and he would periodically turn around and look at the manual, then turn around again and check a voltage or put in a tube.

Now that you have the story, what are you going to do to prevent a similar fatal accident on your ship or station—to save yourself or your shipmates?

Do not work on energized equipment unless it is absolutely necessary.

If it is necessary—remember that 50% of the electrocutions on shipboard involve the so-called lower potentials (nominal 115 volts) and consider all energized equipment a hazard.

Personnel must know their equipment and circuits and hazards involved. Personnel who are not familiar with equipment and fully aware of the hazards involved should not be permitted to service equipment.

Be alert to detect dangerous conditions. If you receive a shock do not consider it as one of the incidental hazards of your job but do something about it. To prevent a reoccurrence with possibly fatal results to you or others. What can you do?

1—Stop and think. How did you get it and why. Be careful that you don't get another shock when you try to find out.

2—Report it to the person responsible for operation and maintenance.

3—Warn others of the dangerous condition.

4—Follow up report to see that corrective action is taken—or take such corrective action if within your jurisdiction.

Much material has been written regarding Safety Precautions, Danger of Electric Shock, etc. and you no doubt have read the following articles, but read them again and make sure that all who work on electronics equipment read them. Make certain that new personnel read them.

1—Chapter 67 of the Bureau of Ships Manual.

2—You Too Can Be a Dead Technician—See ELECTRON, December 1946.

3—Electric Shock (and other pertinent data)—BuShips Bulletin of Information #29, 1 January 1948.

4—Effects of Electric Shock—See ELECTRON, March 1948.

5—Electric Shock Fatalities in Naval Service and Lessons to be Learned from Them.—See BuShips Bulletin of Information #32 of 1 October 1948.

6—See also instruction books for equipments you use and warnings therein—all instruction books.

7—Safety Poster—Electric Shock First Aid Treatment—NAVMED 123.

TEN LIVES SAVED BY GCA

A recent dramatic instance of the life-saving value of GCA has been brought to the attention of the Bureau of Ships by the Electronics Officer, USNAS, Squantum, Mass.

At 0300 on Thursday, 27 April 1950, the O.O.D at USNAS, Squantum, was called by the Boston Air Route Traffic Control at Boston's Logan Airport, with a request for assistance in locating an Air Force C–47. The plane was on a flight from Goose Bay, Labrador to Westover Air Force Base, Massachusetts. This was the next to last leg for the plane belonging to the 2105th Air Weather Squadron, Wiesbaden, Germany, on a flight from Wiesbaden to Rome, New York. The plane had failed to report in over Portland, Maine, at the required time. It was noted that a severe magnetic storm was in progress.

The O.O.D immediately alerted GCA Unit 21, and manned the newly installed AN/URD–2 VHF/DF in the control tower at Squantum, using 121.5 Mc. as advised by the Boston Air Route Traffic Control. It was immediately noted that other activities were calling the plane in question, Air Force 8876, on that frequency, with no success. Squantum established contact with the plane on that frequency almost at once and succeeded in establishing the position of the aircraft at a point some 20 miles off the Maine coast, near Portland. The plane was brought over the field with the aid of DF and then turned over to GCA. The GCA crew picked up the plane on their scopes when some 25 miles out and reported range and bearing until they took over. The plane landed under GCA control at 0330. No other fields in the area were open and none had a GCA or DF. The plane carried a crew of 5 plus 5 passengers, who were very grateful indeed for the GCA/DF combination. They reported that the magnetic storm had rendered all of their radio equipment useless, except for VHF, and that their compasses were somewhat erratic.

USE YOUR ECHO BOX

by Lt. (jg) R. V. Weaver *and* R. G. Walker
Staff, ComServLant, Norfolk, Va.

The echo box, though it may seem small and insignificant in comparison with the large and relatively complex radar equipments with which it is used, is actually very important in the maintenance and adjustment of that equipment. Intelligent use of the echo box will aid the ET greatly in analyzing the performance of his equipment and in keeping it in peak operating condition.

Briefly, the echo box consists of a resonant cavity which is caused to oscillate by energy from the transmitter pulse. At its simplest the echo box may consist of an untuned cubical metal box with a small probe inserted into one corner of the cube and connected by coaxial cable to the radar transmitter. The cavity is driven into oscillation by energy from the transmitter pulse and after each pulse, returns energy at the transmitter frequency to the receiver.

More complicated echo boxes may use tunable cavities and include a detector or voltage measuring device of some kind. The simplest voltage indicator is a neon bulb coupled into the resonant cavity which glows when the r-f energy of the oscillations is great enough. More refined voltage indicators consist of a vacuum tube voltmeter, or a diode rectifier and microammeter.

Tunable vacuum tube voltmeter echo boxes are ordinarily used with v-h-f radars such as the SC, SK and SRa series. The echo box is coupled to the radar by means of a small dipole near the radar antenna. This type of installation has the serious disadvantage of not giving an appreciable ring time response on the indicator scope and for that reason is not especially valuable for tuning the receiver. However, it is useful for checking transmitter power output and frequency applications that are often neglected, in spite of the fact that the echo box is the best means of tuning the transmitter. The oscillator, coupling, and tuning stub controls are tuned for maximum meter deflection. It may be necessary to try tuning up on several frequencies before finding the one giving maximum power output. This assures maximum radiation of power from the antenna. The receiver and duplexer are then tuned on target echoes.

Microwave echo boxes are supplied in a variety of types ranging from un-tuned cavities to precisely machined tunable echo boxes that are capable of quite accurate frequency and power measurements. In most installations they may be coupled to the transmitter either by a dipole of appropriate size mounted near the antenna or by a "directional coupler" mounted on the waveguide near the transmitter. The untuned echo box (usually furnished only with X-band fire control equipment), is capable of furnishing a check on overall performance by recording ringtime, and is a means of tuning the local oscillator without targets.

Tunable microwave echo boxes have a much greater variety of uses, though they vary in complexity and refinement. One simple S-band echo box uses a neon bulb as an indicator. It has a cam lever for quickly detuning it so the echo box return will not mask nearby targets.

To use this echo box throw the cam lever in the direction of the neon bulb and adjust the knurled nut for maximum glow in the bulb. This tunes the echo box to the transmitter frequency. The TR cavity and local oscillator may then be adjusted for maximum ring time. This echo box is not calibrated and thus cannot be used to check frequency or determine the magnetron spectrum. However, it does furnish a useful check on overall performance and a means of tuning the radar in the absence of targets. When the echo box is not in use the cam lever is moved down in the opposite direction from the neon bulb.

Precision tunable echo boxes using crystal diode rectifiers and microammeters are available to cover wavelengths from 30 centimeters to 3 centimeters. These echo boxes can furnish the ET with a great deal of information, ranging from overall performance and reasonably accurate frequency measurements to clues to defective components in the radar equipment. It is possible to detect defective TR tubes, magnetrons and modulator performance. The echo box may also be used to set the local oscillator frequency on the proper side of the magnetron frequency, and to tune the equipment in the absence of targets.

A defective magnetron having a poor spectrum or low power output, or a magnetron that is moding may be found by plotting a rough "frequency spectrum" of the transmitted pulse. All that is necessary is a series of readings of the power output as measured by the echo box taken at small intervals of dial setting across the band of frequencies in which energy is being radiated. A plot of relative power output against frequency gives the frequency spectrum.

A transmitter in good condition should have one fairly narrow peak with deep minimum points on either side. The two sides should be symmetrical and should have only one or two small secondary output peaks on either side of the main or center frequency. A curve with broad sloping sides rather than sharp drops on either side of the main peak indicates frequency modulation of the transmitter during the pulse; a curve with two fairly large peaks instead of a single one indicates double-moding in the magnetron.

When the radar transmitter is producing a good, or at least a fair, frequency spectrum curve the distance between the two minimum points at each side of the main peak is an indication of the length of the transmitted pulse. Pulse duration in microseconds may be roughly determined by dividing the number two by the distance between the two minimum points of the spectrum in megacycles. Look in the echo box instruction book for the method of converting the dial reading into frequency in megacycles.

"Pulling" of the magnetron off frequency by a defective rotating joint or an object near the antenna may be detected by means of the echo box also. It will show up as a varying echo box response, or ring time, on the PPI as the antenna rotates. The echo box meter reading will also vary with different antenna bearings even though the echo box is connected to the transmitter by means of the directional coupler attached to the waveguide.

A defective TR tube giving long recovery time shows up as a dip in the echo box response near the left end of the trace on the A-scope or as a slightly darker ring in the center portion of the echo box response on the PPI.

Precision echo boxes must be carefully maintained if satisfactory results are to be obtained. Do not attempt repairs or adjustments without consulting the instruction book. Echo box pickup dipoles should be megged periodically. In general, a reading of over 50,000 ohms is satisfactory, while a lower resistance reading indicates that repairs are necessary. Exposed coaxial fittings are a common source of trouble. They should be taken apart, cleaned, coated with silicone compound (Dow-Corning No. 4 Ignition Sealing Compound or equivalent), then reassembled, wrapped with rubber tape and friction tape to keep out moisture. Always use the same cable to connect the echo box to the directional coupler in order to avoid variations in ring time readings.

Low ring time readings from externally mounted untuned echo boxes used with fire control radars may sometimes be traced to leakage in the coaxial cable fitting or the capacitive coupling probe screwed into the corner of the echo box. The probe should be removed, cleaned, coated with silicone compound, and replaced. The coaxial fitting should be treated as described previously for pickup dipole coaxial fittings.

Complete discussions of all the uses of the echo box will be found in the echo box instruction book. The books for precision echo boxes such as the OBU series, which have such a wide scope of uses, give a great deal of information concerning the interpretation of the various readings obtained, correct methods of making frequency spectrum curves, reading the value of ring time correctly, etc.

Because there is so much to be learned about the radar and its performance from the associated echo box, it is well worth a few hours of the ET's time to carefully read the instructions for the echo box equipment installed in his ship, learn all its uses, and maintain it in the best possible operating condition. This may save many hours of time in locating defective components and will greatly help in obtaining the best results from the radar equipment.—*ServLant Monthly Bulletin.*

COMMUNICATION TESTS FOR VESSELS BEING OVERHAULED

Communication test facilities for vessels undergoing overhaul are being made available at various Naval shipyards.

A good example is the procedure described in Naval Shipyard Boston Electronics Office Memorandum #26–49. This is quoted below for information:

"1—As a service to vessels having availability at the Boston Naval Shipyard, provisions for communication tests have been inaugurated as set forth below.

"2—Tests may be conducted on Mondays to Thursdays, inclusive, from 1000 to 1100 or from 1400 to 1500. Vessels must make arrangements in advance for this service by calling Mr. J. Valencia, Shipyard extension 161 or by contacting the Electronics communication engineer assigned to the vessel.

3—Tests will include checks of signal strength, modulation and keying, if desired. Signal strength will be recorded in decibels. Special facilities are available for TDZ tests. A report, including copies of all readings, will be forwarded to the vessel if requested at the time that arrangements for the tests are made.

"4—The following frequencies are available for use:

TDZ-RDZ	*AN/ARC-1*	*TBS*
1) 277.8 Mc	1) 116.1 Mc	72.1 Mc
2) 328.2 Mc	2) 142.74 Mc	72.9 Mc
3) 339.4 Mc	3) 145.08 Mc	
4) 371.4 Mc	4) 145.80 Mc	TDQ/RCK
5) 309.0 Mc	5)	116.1 Mc
6) 336.2 Mc	6) 134.64 Mc	140.58 Mc
7) 386.6 Mc	7) 143.64 Mc	142.02 Mc
8) 318.6 Mc	8) 142.02 Mc	
8) 318.6 Mc	9) 142.56 Mc	*MISC. LF/HF*
10) 243.0 Mc	10) 140.58 Mc	300 kc to
		18,100 kc

"5—A copy of this notice will be furnished each vessel upon its arrival at the Shipyard. This service is available regardless of whether or not repair or installation of communication equipment is made during the availability."

Interference Attenuation of Resistor Type Spark Plugs

by
WILLIAM A. RITZ
Electronics Shore Division,
Bureau of Ships

The results of electronic interference surveys recently conducted by the Bureau of Ships at fifteen Naval shore activities, indicate that unsuppressed ignition systems of vehicles is the major source of interference to communications and electronic equipments at these activities, when these vehicles or auxiliary equipment powered by internal combustion engines, are operated within 1,000 feet of receiving antennas. At many Naval shore activities vehicles are normally operated within 50 feet of receiving antennas, and it has been found common practice to locate parking areas under or in close proximity to receiving antennas.

The generation of high voltages by ignition systems and subsequent discharge of this electrical energy across spark plug gaps produces a radiated interference rich in harmonics due to the steep front of the resultant pulse wave train, with harmonics covering many portions of the radio-frequency spectrum. These transient pulses of high amplitude "shock excite" the affected receiver even though the interference impulses may not have a component at the resonant frequency of the receiving circuit. The radio-frequency wave produced by the ignition system may be an ultra-high-frequency wave, modulated at the oscillating frequency of the arc created by the spark action. The amplitude of this ultra-high-frequency carrier wave may be so high that the first stage of the receiver becomes saturated, resulting in rectification of the received impulses, permitting the low-frequency modulation componnt of the arc to appear in the receiver. The resultant noise heard in the output of communication receivers is at the spark repetition rate of the interfering ignition system, changing in pitch with changes in engine speed.

U.S. Naval Air Station, Quonset Point, R. I., showing vehicles and parking area under antennas.

View of tower and receiving antenna for radio operations, NAS, Boca Chica Field, Key West, showing vehicles parked in vicinity.

Ignition interference from vehicles and certain auxiliary power supplies is effectively radiated at high amplitudes up to approximately 1000 feet. A distinguishing characteristic of motor ignition interference is that the intensity increases with an increase of frequency (up to 400 megacycles), which is at variance with the usual decrease of interference intensity with an increase of frequency, characteristic of other common sources of radio interference, with the possible exception of high-frequency medical equipment. Ignition interference increases also as the bandwidth of the receiver is increased, and is regarded as the major source of interference to television receivers due to the high frequencies and wide bandwidths presently used in these receivers.

Electronic interference radiated from an ignition system may be attenuated in varying degrees by employing one of the following methods:

1—Complete enclosure of the entire ignition system in a shielded harness.

2—The insertion of resistors, resistor type spark plugs and filters at appropriate points in the ignition system.

Considerable research and developmental work has been expended in the development of shielded ignition system kits designed for installation on the engines of motor vehicles and certain auxiliary equipment powered by internal combustion engines. These shielded ignition system kits, if properly installed and thereafter subjected to constant and exhaustive maintenance techniques will attenuate the radiated electronic interference to within the limits set forth by Bureau of Ships Specification 16E4. Past experience with shielded ignition systems installed in planes, vehicles and on crash boats has demonstrated that without this continuous maintenance, the value of shielded ignition systems as an electronic interference reduction medium, is soon nullified.

There are no shielded ignition system kits presently available for installation on vehicles at Naval shore activities, due to the extremely high cost of this type kit, the very limited number of vehicle types for which shielded ignition system kits have been developed, and the magnitude of the maintenance problem involved.

The problem of ignition interference to communications and electronic equipments at Naval shore activities has assumed major proportions necessitating that prompt corrective action be taken to reduce this type interference to the greatest extent practicable. Due to the presently existing limitations on the availability of shielded ignition system kits, it became necessary to investigate the desirability of employing resistor type spark plugs as an interim measure. Accordingly field engineering tests were conducted by the Bureau of Ships at the Naval Air Station, Atlantic City, New Jersey; the Charleston Naval Shipyard, Charleston, South Carolina; and at the David Taylor Model Basin, Carderock, Maryland, on three different types of motor vehicles to determine the electronic interference attenuation characteristics of resistor type spark plugs. The results of these tests which are summarized in this article, indicate that appreciable attenuation of radiated electronic interference may be obtained by this method throughout the radio-frequency spectrum from 14 kc to 400 Mc, with complete elimination of interference possible throughout large portions of the above frequency spectrum. The use of external resistors in the high tension leads to the spark plugs and distributor of an internal combustion engine to suppress radiated electronic interference has been common practice for many years with varying degrees of suppression effectiveness. Certain types of resistors have been found to be exceedingly poor in their ability to suppress electronic interference produced by radiations from ignition systems. This is true in spite of the fact that their resistance values as measured on instruments commonly used for this purpose were the same as those obtained with resistors of other compositions that proved to be effective for the suppression of interference. It has been determined that the basic cause for the noted differences in suppression effectiveness is due to the effect of operating voltages and temperatures on the resistance value of resistors of various compositions. Investigations established the fact that the effective suppression of ignition interference by means of resistance value of approximately 6,500 ohms under actual operating conditions.

The Champion Spark Plug Company, for example, has standardized on a 20,000-ohm resistor for use in resistor type spark plugs manufactured by that company. The resistance characteristics of this 20,000-ohm resistor under various voltage and temperature conditions (applied simultaneously) are shown in Chart No. 1. Referring to the family of curves on this chart, it will be noted that even under the voltage and temperature conditions comparable to actual service, the 20,000-ohm resistor (having a range of tolerances from 16,000 to

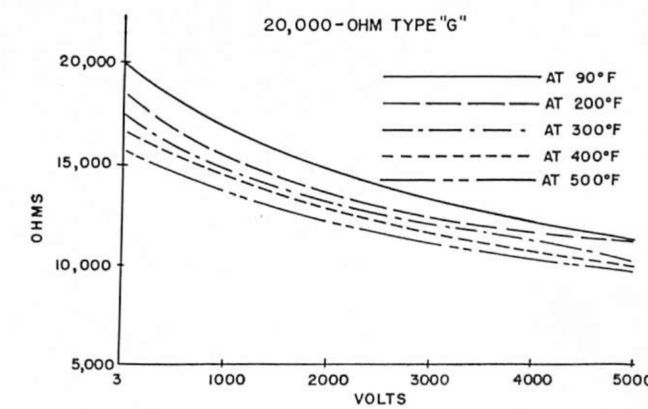


CHART I—Resistance characteristics of Champion Spark Plug Co. 20,000-ohm resistor type spark plugs under various voltage and temperature conditions.

Investigation of ignition system interference at NAS, Atlantic City, N. J.

24,000 ohms) provides a minimum resistance exceeding 6,500 ohms.

Test number one was conducted at the Naval Air Station, Atlantic City, New Jersey, using a 1943 Autocar gasoline refueling truck for test purposes. This particular truck is normally parked and operated within a radius of approximately 50 to 1000 feet from the control tower and associated receiving antennas mounted thereon. An electronic interference survey of this activity prior to this test, had disclosed this truck as a major source of interference to control tower communications. Reports indicated that reception on 6390 kc (the control tower crash frequency) was virtually impossible during the periods when this truck was in operation.

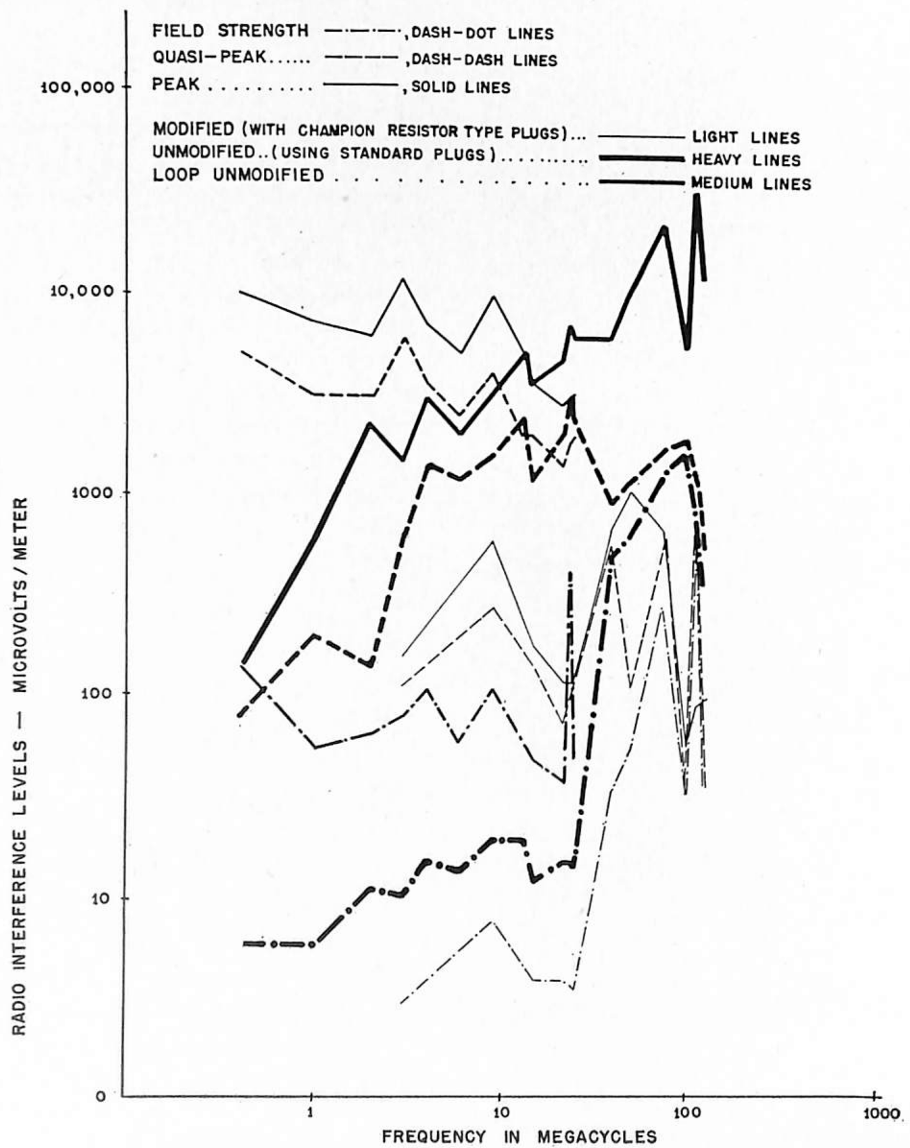


CHART 2—This chart illustrates information contained in Tables Nos. 1 and 2.

Table No. 1

	Loop			Rod			
Freq.	*F.S. μv/m*	*Quasi Peak μv/m*	*Peak μv/m*	*F.S. μv/m*	*Quasi Peak μv/m*	*Peak μv/m*	*Notes*
400 kc	140	5000	10000	6	80	140	Generator only
1 Mc	55	3000	7000	6	200	600	Ignition
2 Mc	65	3000	6000	12	1400	2200	Ignition
3 Mc	80	6000	12000	11	600	1500	Ignition
4 Mc	110	3500	7000	16	1400	3000	All generator, little ignition
6 Mc	60	2000	5000	14	1200	2000	Voltage regulator
9 Mc	110	4000	10000	20	1600	3200	Voltage regulator
13 Mc	60	2000	5000	20	2400	5000	Peak of voltage regulator
15 Mc	48	2000	3500	13	1200	3600	Ignition and generator, start of voltage regulator
22 Mc	38	1400	2800	16	2000	4600	Ignition
24 Mc	425	1800	3000	16	3000	7000	Ignition
25 Mc	50	2000	3500	15	2400	6000	Ignition
40 Mc				501	912	6080	Ignition
50 Mc				644	1145	10166	Ignition
75 Mc				1475	1729	23100	Ignition
100 Mc				1696	1930	5415	Ignition
115 Mc				908	1240	33210	Ignition
125 Mc				384	568	12240	Ignition

Vehicle tested—Navy gasoline truck No. 166992
Type vehicle—1943 Autocar, 6 cylinder
Date of test—28 May 1950
Type test—radiated ignition interference
Conditions—Original spark plugs, installed, measuring equipment located three feet from engine, compartments on truck closed, speed approximately 15 miles per hour.

Table No. 2

	Rod			
Freq.	*F.S. μv/m*	*Quasi Peak μv/m*	*Peak μv/m*	*Notes*
3 Mc	3 ambient	Voltage regulator pulses 40–120	160	No ignition, voltage regulator and generator only
9 Mc	8 ambient	Voltage regulator pulses 280	600	No ignition, voltage regulator and generator only
15 Mc	4 ambient	Voltage regulator pulses 80–140	180	No ignition, but generator increase
22 Mc	4 ambient	Voltage regulator pulses 40–70	120	No ignition, voltage regulator only
25 Mc	3.6 ambient	Voltage regulator pulses 80–200	120	No ignition, voltage regulator only
30 Mc	16	60	96	Ignition and voltage regulator
40 Mc	35	586	708	Ignition and voltage regulator
50 Mc	55	114	1173	Ignition and voltage regulator
75 Mc	295	617	6930	Ignition and voltage regulator
100 Mc	33	38	577	Ignition and voltage regulator
115 Mc	635	827	922	Ignition and voltage regulator
125 Mc	38	34	1020	Ignition and voltage regulator
125 Mc	19.2	19.6	510	TS-587/U dipole moved 15 feet from vehicle

Measurements were first made of the electronic interference levels created by operation of this truck with conventional spark plugs installed. The AN/PRM-1 and the TS-587/U were used to measure the electronic interference over the radio-frequency spectrum from 400 kc to 125 Mc at a distance of three feet from the engine which is located under the driver's seat. The results of this test are contained in Table No. 1 and Chart No. 2.

At the conclusion of the test outlined by Table No. 1, the original spark plugs were removed from the Autocar gasoline truck and replaced by "Champion" resistor type spark plugs. The test was then repeated with the results shown in Table No. 2 and Chart No. 2.

NOTE: Filters placed on generator and voltage regulator will virtually eliminate the interference from these sources.

It will be noted from Table No. 2 that ignition inter-

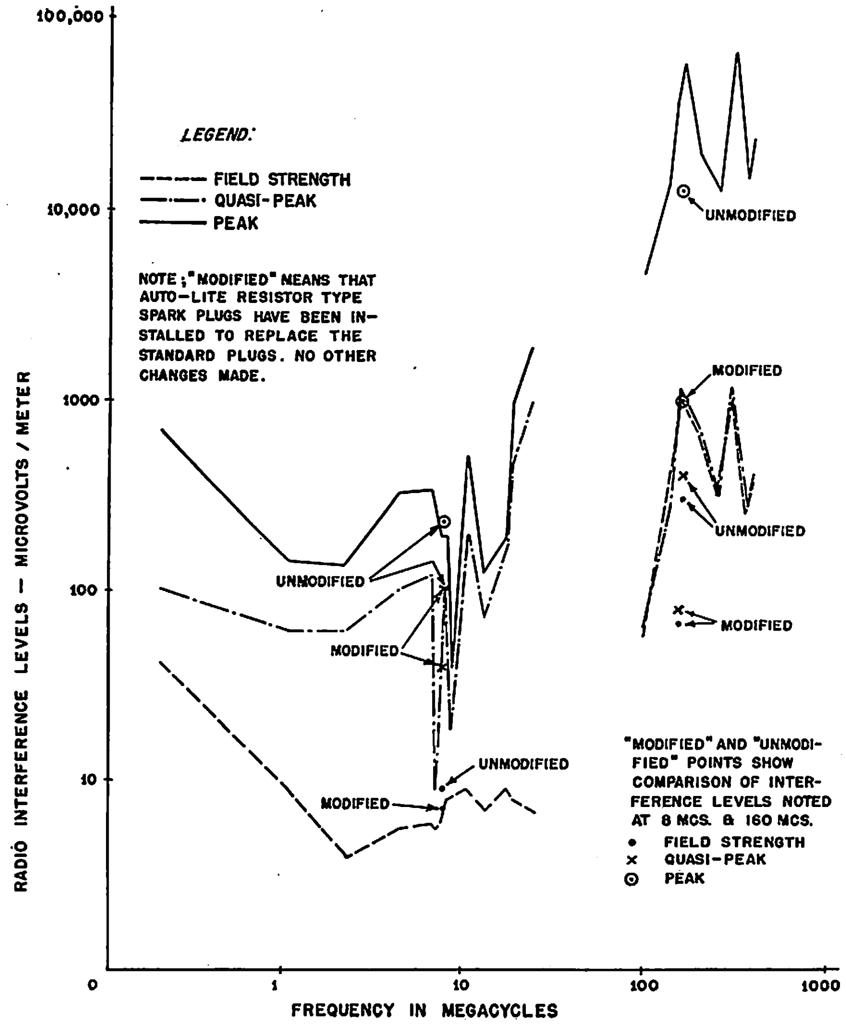


CHART 3—This chart illustrates information contained in Table No. 3.

Table No. 3

Vehicle tested—Navy station wagon
Date of test—25 May 1950
Type of test—Radiated ignition interference
Conditions—Original spark plugs installed, measuring equipment located 3 feet from vehicle engine, hood down, engine speed approximately 20 miles per hour.

Freq.	*F.S. µv/m*	*Quasi Peak µv/m*	*Peak µv/m*
0.2 Mc	40	100	700
1.15 Mc	9	60	140
2.4 Mc	4	60	130
4.8 Mc	5.6	100	320
7 Mc	6	120	340
7.5 Mc	5.6	9	210
8 Mc	6.2	70	190
8.5 Mc	8.0	100	190
9 Mc	2	18	38
10.6 Mc	9	200	500
14 Mc	7	70	120
17.5 Mc	9	160	180
20 Mc	8	450	950
25 Mc	7	950	1800
100 Mc	56.2	61.8	4500
140 Mc	416	279	13400
150 Mc	659	659	36200
160 Mc	1079	1079	55100
170 Mc	822	857	71400
200 Mc	646	686	18300
250 Mc	317	317	12000
300 Mc	1146	1146	62450
350 Mc	258	274	14730
380 Mc	358	394	22200

ference was eliminated by these plugs below approximately 30 megacycles. Following these tests, the truck was operated directly under the receiving antennas, with no electronic interference discernible in any of the control tower receivers.

Test No. 2 was conducted at the Charleston Naval Shipyard, Charleston, South Carolina on 25 May 1950. The vehicle selected for this test was a Navy station wagon number 184004. The conditions and results of the first series of measurements are contained in Table No. 3 and Chart No. 3.

Following the first series of measurements, the results of which are given in Table No. 3, tests were conducted to determine the attenuation characteristics of the radiated ignition interference with distance. Two tests were made, one at 160 megacycles and another at 8 megacycles. Measurements were made at various distances from 3 feet to 25 feet, both with the original spark plugs installed and with "Autolite" resistor type spark plugs installed. Results are shown in Tables No. 4 and No. 5, and Charts Nos. 4, 5 and 6.

Test Number Three was conducted at the David Taylor Model Basin, Carderock, Maryland on 24–26 May 1950. The vehicle selected for test purposes was a 1940 DeSoto sedan, chosen because it was typical of the type vehicle normally driven on Naval stations by military and civilian personnel.

Table No. 4

Vehicle tested—Navy station wagon
Date of test—25 May 1950
Type test—Radiated ignition interference
Conditions—Measurements made at 160 megacycles, using the TS–587/U placed at various distances from vehicle; speed of vehicle approximately 20 mph. Two sets of measurements were made, the first with the original plugs installed and the second with "Autolite" resistor type spark plugs installed.

	Original Plugs Installed			*"Autolite" Resistor Type Spark Plugs Installed*		
Distance	*F.S. µv/m*	*Quasi-Peak µv/m*	*Peak µv/m*	*F.S. µv/m*	*Quasi-Peak µv/m*	*Peak µv/m*
3 feet	295.2	350.5	12600	66.5	70.1	1620
5 feet	258.5	250.5	9000	44.3	48	1260
7 feet	129.1	129.1	3965	18.5	22.9	647
11 feet	110.8	129.1	3600	9.23	11.4	351
13 feet	73.9	73.9	2700	5.54	6.28	188
15 feet	73.9	73.9	3645	3.32	3.7	111
17 feet	73.9	73.9	2880	3.7	4.4	111
19 feet	59.1	66.5	2160	4.8	4.8	166
21 feet	55.4	59.1	1800	4.4	4.8	110
23 feet	55.4	59.1	1620	4.4	4.4	111
25 feet	59.1	66.5	1980	3.7	3.7	111

The investigation of this vehicle, a 1940 DeSoto sedan, revealed extremely high levels of radiated electronic interference previous to the installation of suppression equipment. Measurements of radiated electronic interference were made over the radio-frequency spectrum from 15 kilocycles to 400 megacycles using the following test equipments:

1—AN/URM–6
2—AN/PRM–1
3—TS–587/U

The major source of interference was identified as ignition noise from the spark plugs and distributor.

The test equipment was set up on a concrete loading platform and the vehicle placed at the loading position facing the platform. Antennas for the AN/URM–6 and TS–587/U were placed at ground level and positioned in front of the vehicle. All measurements were made with antennas three feet from the vehicle unless otherwise noted. The vehicle was operated at an approximate engine speed corresponding to 15 mph.

A visual inspection of the vehicle revealed no suppression with the exception of by-pass condensers on the generator and ammeter which were removed for the pre-suppression tests.

Radiated electronic interference levels are shown by

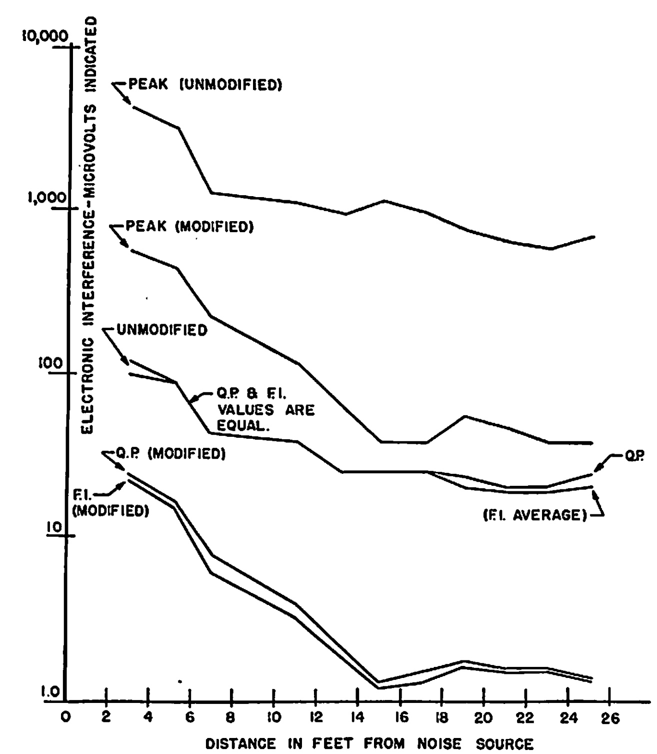


CHART 4—This chart illustrates information contained in Table No. 4.

Charts Nos. 7, 8 and 9 for both the unsuppressed and suppressed conditions.

The suppression equipment installed consisted of six "Autolite" resistor spark plugs #AR–8–14MM and two Cornell-Dubilier #A–30880 by-pass condensers, one on

Table No. 5

Vehicle tested—Navy station wagon
Date of test—25 May 1950
Type teste—Radiated ignition interference
Conditions—Measurements were made at 8 megacycles using the AN/PRM–1 placed at various distances from vehicle, speed of vehicle approximately 20 mph. Two sets of measurements were made, the first with the original plugs installed and the second test with "Autolite" resistor type spark plugs installed.

	Original Plugs Installed			*"Autolite" Resistor Type Spark Plugs Installed*		
Distance	*F.S. μv/m*	*Quasi-Peak μv/m*	*Peak μv/m*	*F.S. μv/m*	*Quasi-Peak μv/m*	*Peak μv/m*
3 feet	9	100	220	7	40	100
5 feet	8	80	140	7	40	100
7 feet	7	50	110	6	30	90
11 feet	6	40	100	5	20	60
13 feet	5	36	80	5	15	36
15 feet	5	36	80	5	12	20
17 feet	5	32	80	4	9	14
19 feet	5	32	70	4	7	15
21 feet	4	28	60	4	7	15
23 feet	4	20	40	4	6	20
25 feet	4.2	18	40	3	5	24

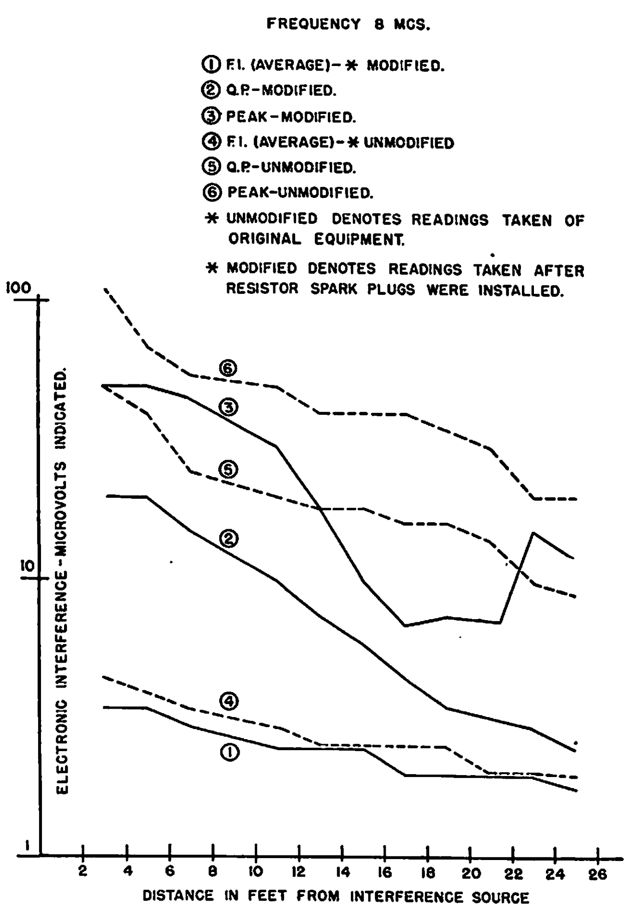


CHART 5—This chart illustrates information contained in Table No. 5.

the generator and one on the ammeter. The spark plug gaps were set at 0.040″ in accordance with manufacturers' specifications.

A test was made at 3100 kilocycles with the vehicle suppressed. The equipment used was the AN/PRM–1 with the AT–211 test antenna and the CG–444 20-foot cord. It was found that, with the equipment noted above, it was necessary to get within the following distances to obtain an indication on the meter:

1—spark plugs—5 inches

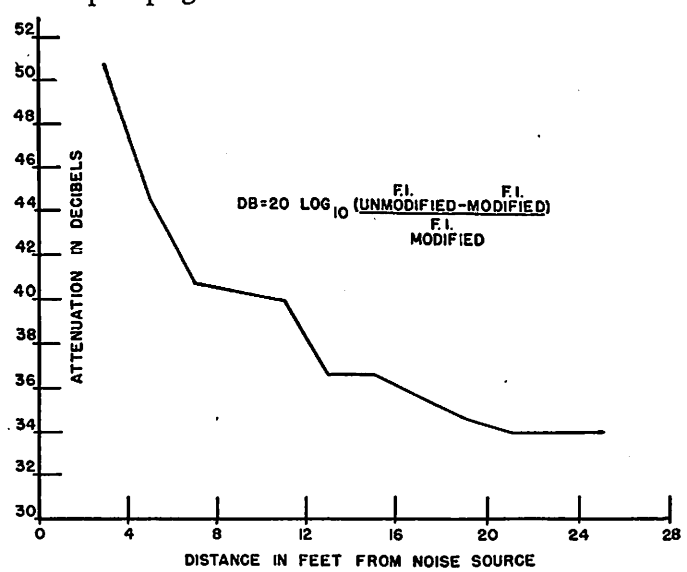


CHART 6—This curve is derived from the F.I. curves of Charts Nos. 4 and 5, showing the DB difference between the modified and unmodified curves.

2—generator—2 inches
3—distributor—1 inch

A test was made at 140 megacycles with the vehicle operating at an estimated engine speed corresponding to 15 mph in both the unsuppressed and suppressed conditions. The results of this test are shown in Chart No. 10. The equipment was kept stationary and the vehicle moved away from the antenna in steps, as shown on the graph.

Analyzing the results of the three engineering tests described in this article, it becomes apparent that wide variations exist in the interference levels created by different vehicles, and that resistor type spark plugs produced by individual manufacturers may differ greatly in their interference suppression effectiveness due to the effect of high operating voltages and temperatures on the value of the resistance element used in the manufacture of the spark plugs.

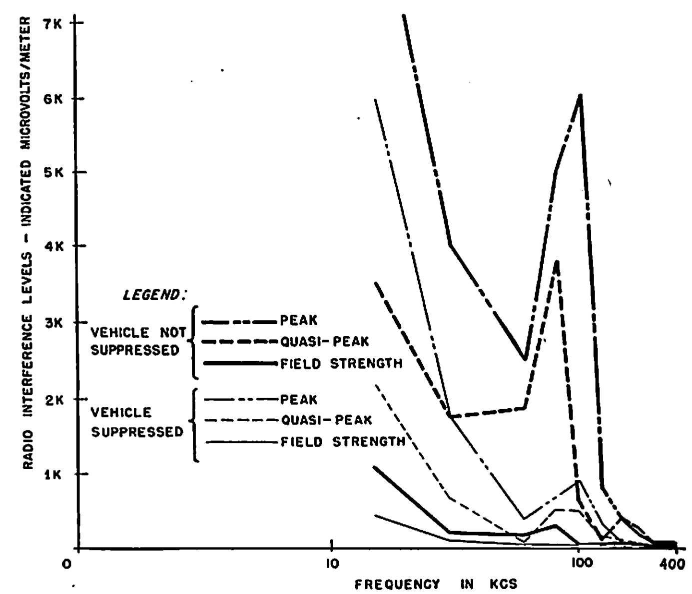


CHART 7—Radiated radio interference measurements made of 1940 DeSoto sedan.

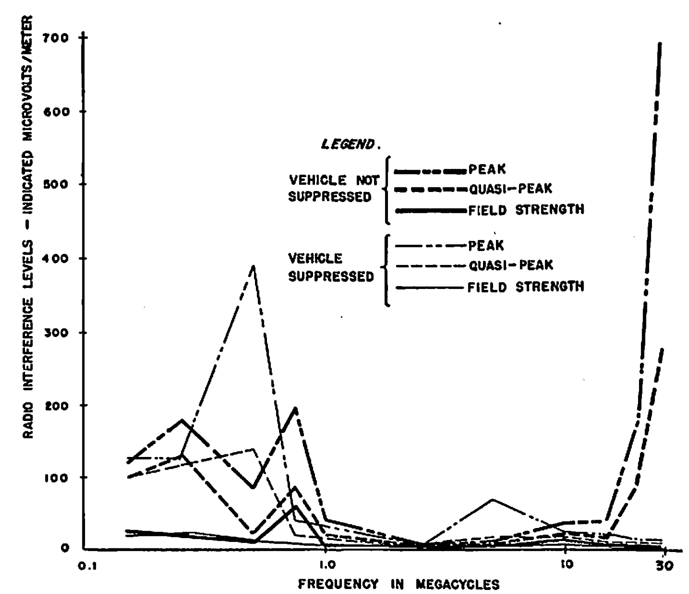


CHART 8—Further radiated radio interference measurements made of 1940 DeSoto sedan.

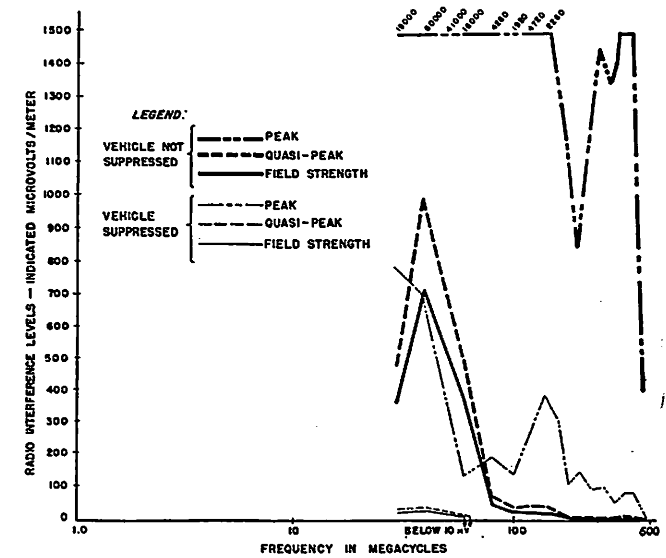


CHART 9—Further radiated radio interference measurements made of 1940 DeSoto sedan.

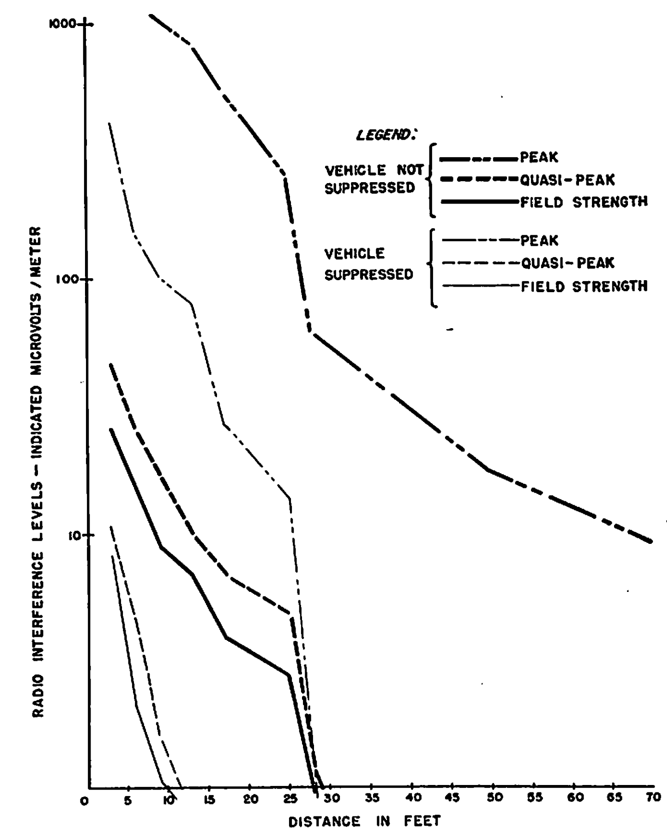
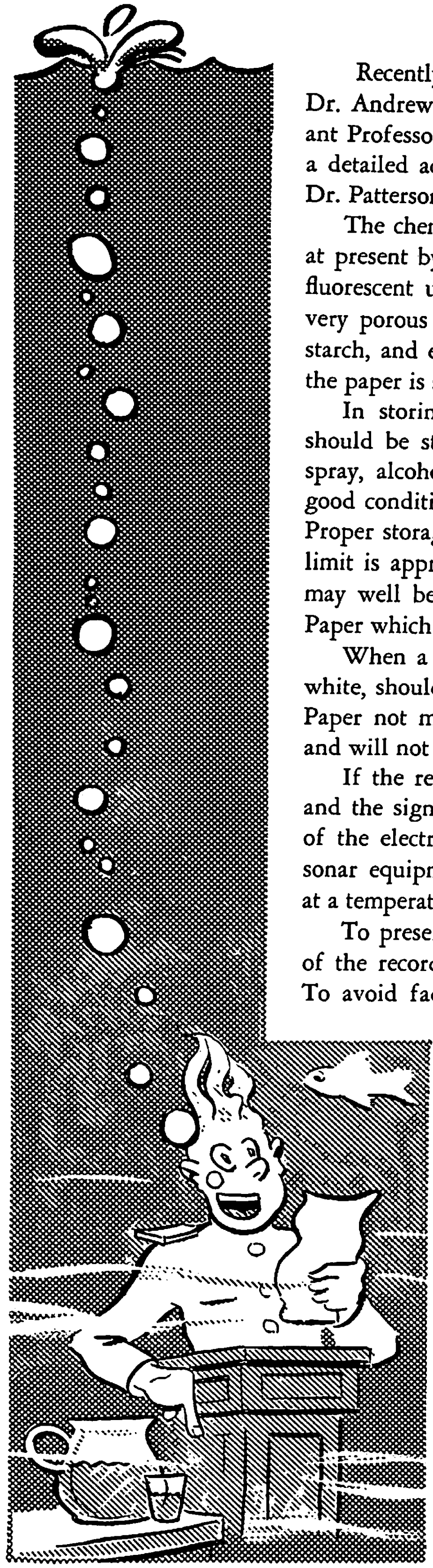


CHART 10—Radiated radio interference of 1940 DeSoto sedan, showing attenuation as a result of increasing distance between antenna and vehicle.

USN USL notes

STORAGE AND USE OF CHEMICAL RECORDER PAPER



Recently, after a number of discouraging experiences with chemical recorder paper, Dr. Andrew Patterson, Jr., a part-time consultant in physics at the Laboratory and Assistant Professor of Chemistry at Yale University, undertook a study of the problem. While a detailed account of the study can not be given here, it is believed that a summary of Dr. Patterson's findings will be of interest to the readers of ELECTRON.

The chemical recorder paper which has been available in the past and which is issued at present by the Navy Department is a starch-iodide paper with eosin added to make it fluorescent under ultraviolet light. A comparatively heavy paper base, which is neither very porous nor absorbent, is impregnated with a solution of potassium iodide, cooked starch, and eosin. An anti-bacterial agent, such as mercuric iodide, may be present, since the paper is stored and used in a moist condition.

In storing starch-iodide paper, certain precautions should be observed. The paper should be stored in a place free from fumes, flue gases, tobacco smoke, galley odors, spray, alcohol vapor, etc., in order to prolong the time during which it will remain in good condition. The procedure is not of prime importance if the paper is well packaged. Proper storage requires a cool location in which there is no danger of freezing; the lower limit is approximately 25° F. If the paper is not hermetically canned, the storage space may well be damp, since even with the usual packaging some loss of moisture occurs. Paper which has been opened should be kept in a very subdued light.

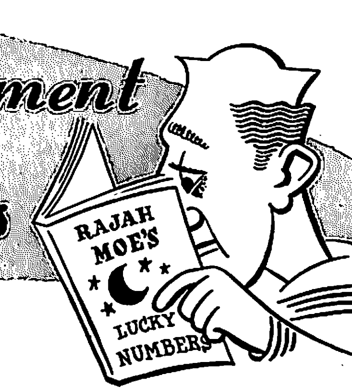
When a package of paper is opened for use, the contents should be a clear pink or white, should show no trace of blueness, and should be limp and quite moist to the touch. Paper not meeting these requirements will have a lowered sensitivity and poor contrast and will not be suitable for preservation of records.

If the records to be taken are to be preserved, the paper must be in good condition, and the signals must be adequate in order to give readable traces. Optimum adjustment of the electronic equipment, proper biasing, and careful monitoring of the gain of the sonar equipment are essential. During the recording process, the paper should be kept at a temperature of around 70° F.

To preserve well-recorded traces, the paper should be payed out freely from the face of the recorder and should be dried out as quickly as possible without the use of heat. To avoid fading and bluring, the paper should, if possible be kept away from fumes, flue gases, tobacco smoke, galley odors, spray, alcohol vapor, etc., during the recording process, and adjacent portions of the paper should not be allowed to touch. It should be kept in very subdued light while drying and in the dark during storage. On shipboard, it is advisable to store the electrolyzed paper, loosely rolled, in a desiccator which may be made from a metal can with a tight-fitting cover. A desiccant such as activated alumina, silica gel, calcium chloride, or calcium sulphate should be used. Dehydrants can be obtained which are colored and change color when exhausted, providing a simple and desirable check on the condition of the desiccant. "Indicating Drierite" is satisfactory for this purpose. The paper in the desiccator should be stored in a cool place.

Well-made records on unfogged paper which have faded as a result of aging may be restored temporarily by the following process: A solution of ammonium acetate, $NH_4C_2H_3O_2$, of a concentration such that its viscosity is appreciably greater than that of water, should be prepared. To this solution concentrated ammonia water should be added until a drop of the solution turns an alcoholic solution of phenolphthalein on a piece of porous paper to a pink color. The paper should be dipped in the solution

know your equipment serial numbers



The Bureau of Ships maintains an expensive machine tabulation system. Run properly, this system is worth more than the Bureau spends on it. But—the system is only as good as the data fed into it. It is evident from what follows that slipshod data is being fed the machines.

Example—A DD reports a QHB–1 equipment aboard. Wrong! QHB–1 equipments are exclusively submarine equipments.

Example—Some ship reports QHB–1 equipment Serial 101. Wrong! QHB–1 serials do not run much over 10.

Example—Five vessels report QHBa, Serial 30. Wrong! There is only one QHBa, Serial 30.

Unfortunately, these errors are not easy to catch on individual ships inventories, NavShips 4110. But in NavShips 3551, which is a tabulation by equipment, they are obvious.

The Bureau can attack this problem by checking the ship's 4110 against the ship's Performance and Operation Reports (monthly). But if the serial number submitted in the P & O report differs from the one that the ship or yard submitted in the 4110—that's that. Three solutions to this problem are:

1—Action by the ship:

Be sure you are giving the Bureau the *Equipment Serial Number,* not the serial number of some component of the equipment.

2—Action by the installing yard:

Point out *Equipment Serial Numbers* to ship's force.

3—Action by BuShips Electronics Divisions:

Design a distinctive nameplate for the equipment so that it is distinguishable from component nameplates. In this design, indicate the name of the equipment and its serial number in large print, and subordinate the statements "Contractor ——————" and "Navy Department, Bureau of Ships."

Serial numbers of equipments serve many useful functions, and therefore just a bit more attention should be given to them.

Commanding Officers who desire the latest field changes to electronic equipments and replacement of equipment on an equipment age and operation basis should see that their electronics personnel furnish the Bureau with correct equipment serial numbers.

At this time, the Bureau of Ships is quite anxious to receive correct serials on Models QHB, QHB–1, SR–3, AN/SPS–6, SG–6, and all u-h-f radio equipments. The ship will benefit by the better services the Bureau can make available when correct serial numbers are listed.

Check your equipment serial numbers, and forward notice of discrepancies in NavShips 4110 to the Bureau of Ships, Code 980.

Attention is invited to Page 10 of "Instructions for Maintaining Ship Electronic Equipment Inventory System", NavShips 900,135, which sets forth instructions for maintaining ship electronics inventories.

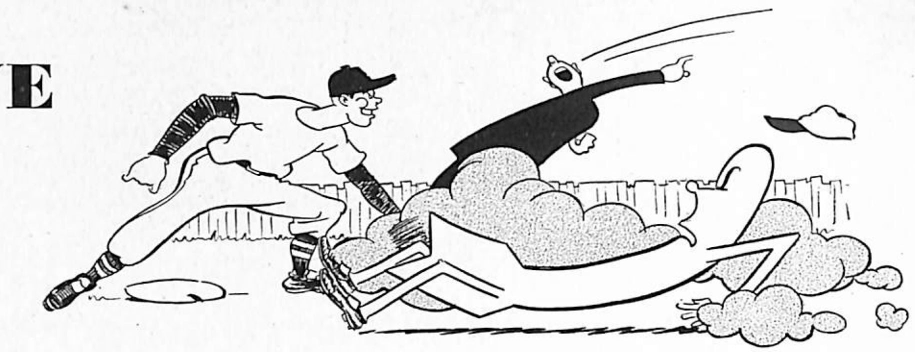
USN USL notes *(Contd.)*

and photographed while it is still damp. If the recorder paper is of the pink variety, the traces should be photographed through a red filter with a tungsten light. A contrasty developer and a contrast film should be used.

Alternatively, and less odoriferously, the following, more elaborate buffer mixture may be employed with equal success: A stock solution consisting of 6.2 grams of boric acid, H_3BO_3, and 7.5 grams of potassium chloride, KCl, in a liter of solution in distilled water should be prepared. A stock solution of sodium hydroxide, NaOH, using 4.0 grams to a liter of solution in distilled water, is also required. Adequate quantities of these solutions should be mixed, using the following proportions: 50 ml of the boric acid stock diluted to 100 ml with distilled water plus 43.9 ml of the sodium hydroxide solution. From this point, the procedure is the same as that for the ammonium acetate buffer.

If the foregoing rules are observed, highly satisfactory results may be obtained with recorder papers, and deterioration upon storage will be greatly minimized.

DEFECTIVE B/T SLIDES



The Hydrographic Office has informed the Bureau of Ships that bathythermograph slides forwarded to that office are flaking. The smoked surface is flaking both during the period of lowering into the water and after lacquering and subsequent handling of the slides.

Some reports have indicated that the possibility of spraying the slides is under consideration. The Bureau does not approve of spraying the lacquer on the slides because it is considered that the force of the spray would tend to break down and destroy the thin film of smoke.

Instructions for inspection of new slides is given in Paragraph 2 of Section 5, Preventive Maintenance, of NavShips 91151 and is reprinted here:

Inspection of New Slides N–100

"Samples of the slides in a new box should be inspected before using. If the smoked surface of a new slide is in bad condition, or if the smoked surface shows spots after lowering the BT, all the slides in the box should be tested by holding each slide under a moderate stream of water. Do not use those slides on which spotting or flaking of the smoked surface appears. The slides should be wiped off and resmoked as described in Section 6."

Paragraph 3, Section 6, Corrective Maintenance, of NavShips 91151 is reprinted here for information as to the proper method to follow when resmoking slides.

Resmoking Slides

"Slides which have been rejected should be wiped off clean with a cloth. Then coat them lightly and evenly with skunk oil. One very small drop of oil is sufficient, and the heel of one's hand serves well to spread it evenly. Be sure to oil and smoke the correct surface of the slide—examine a properly smoked slide to make certain. Smoke the oiled surface by passing it through the top portion of a wide smoky flame. Obtain a thin, even coat. Test samples from each batch by holding 12 to 18 inches under a moderate stream of water. The smoked surface should not spot or flake. A smoking lamp may be made from an empty shoe polish tin with a folded piece of blotter for a wick. Melted candle, paraffin wax, or domestic ceresin wax is poured around the blotter and allowed to harden. A folded edge of the blotter should project above the level of the wax, and should be wide enough to give a flame wider than the slide."

The Bureau does not intend for these instructions to be construed as a directive to resmoke defective slides.

Those vessels engaged in hydrographic operations, which have sufficient space, time, facilities and personnel are privileged to resmoke defective slides in accordance with instructions in NavShips 91151.

It is recommended that preventive maintenance procedures be applied to the slides on board and if flaking is evident, complete full boxes be shipped to the nearest bathythermograph repair facility (Boston, Mare Island or Pearl Harbor Naval Shipyard) for cleaning and resmoking.

The Bureau is considering instructing ESO to ship all slides now held in stock to the three repair facilities to be checked for flaking prior to being shipped to forces afloat.

DISTRIBUTION OF ELECTRON BINDERS AND INDICES

BuShips Electron for May 1950 included an article describing the new Electron binders and indices. All vessels of the active fleet and all flag commands will receive these binders and indices automatically, without further request, in accordance with the allowance of the magazine. The initial procurement made available a sufficient quantity for this action only. Additional copies of this binder will be procured for other activities. Notification of their availability will appear in Electron.

MODEL SP

U.S.S. St. Paul (CA–73)

Scanner motor had burned out on the nutator assembly. The ship was in port under cancelled orders so the ship's force had replaced the motor. Inspection revealed the scanner assembly was frozen. This assembly was removed and taken to the shop in the yard where it was determined that the large double row self-aligning bearing at the front of the waveguide assembly was frozen due to salt water corrosion and lack of lubrication. Since no new bearings were available in spares or at the base, the bearing was removed with great difficulty, washed and cleaned thoroughly, relubricated and reassembled. This disassembly was difficult due to a shortage of the proper tools, although the ship had ordered an antenna tool kit some time previous but same had never been received. Fortunately this tool kit was delivered while repairs were being made on the assembly and proved to be very useful when making the reassembly. Heavy fibre grease had been used in lubricating the assembly at some previous time and this could have been a contributing factor to the motor failure. A thorough search disclosed a small amount of the proper lubriplate for this assembly and when reassembled this lubriplate was used instead of the heavy fibre grease.

The ship also had two train amplidynes which had burned out (motor fields). The last failure of these two was carefully examined which disclosed that the starting winding was badly burned but the main or running winding was in apparently good condition. The starting switch was also charred but the contacts were not harmed. The centrifugal mechanism was operating satisfactorily. Both the motor failures had occurred during severe weather conditions—near typhoon—with the train system locked in 1-speed. It is not known how the current limit potentiometer had been set, and other higher priority work prohibited checking this particular item. The line voltage was normal during the time failure occurred insofar as memory and records could determine. The only explanation for amplidyne failures was that perhaps during heavy weather with 1-speed operation, excessive hunting may have occurred, and with the possibility of the current limit potentiometer being misadjusted, may have caused sufficient overload to burn out the motor. The other possibility is that the motor speed was low due to excessive load, low line voltage, or mechanical drag and stuck in the starting position.

I next inspected the repaired train amplidyne and found that the motor did not turn freely by hand. After removal of the motor and bell the rotor still seemed to be dragging and in addition the brushes were riding over the end of the commutator. There were no shims in the motor and bell. It appeared as if the motor field assembly had some extra varnish on the inside and in addition may have been misaligned slightly causing some dragging. Due to shortage of time, did not correct this difficulty, but instructed the Chief Electronics Technician who said he would take care of the trouble.

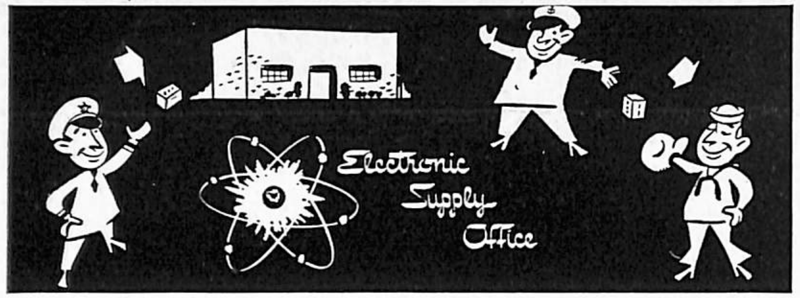
—T. L. Mills, *Pearl Harbor Naval Shipyard*

MODEL TBL–6

This unit timed and loaded nicely up to the last stage of r-f amplification. At that point erratic and unstable operation with parasitic oscillation was indicated. This trouble had been experienced at various periods by the ship's force for some time. A complete check had been made but a complete cure was never found. Various 808's in the driver and final stages were tried with unsatisfactory results. The drive was removed and neutralization of the final was accomplished by adjustment of the control while swinging the final tuning control through its tuning range. At this time, a slight instability was noticed while trying to neutralize. Recommended the installation of a parasitic choke in the grid circuit of the final 808 r-f amplifier, consisting of a 20-ohm 2-watt resistor and about 6 turns of #14 wire shunting the resistor. This choke was made and installed resulting in improved stability and no loss of output.

—H. C. Broderson

Bureau Comment: *This was one engineer's method of solving a local problem. It is pointed out that this is not a bureau-approved change but was only made to obtain satisfactory operation during an emergency. If other activities have had similar difficulties, the Bureau is interested in the method used to solve same. It is requested that such maintenance procedures be reported to the Bureau of Ships, Code 980.*



E.S.O. MONTHLY COLUMN

HOW MANY PARTS PECULIAR?

Suppose you had the job of telling how many parts peculiar should be furnished as maintenance parts for a new equipment. How would you go about making your decision?

The solution to this problem is found in the Bureau of Ships Specification 16E6. This document sets up a procedure whereby experienced personnel from BuShips, ESO, manufactures' engineers, and, where possible, shipyard maintenance experts analyze the equipment being procured piece by piece to determine the number of peculiar parts required to maintain it for its lifetime.

This specification contains complete instructions for determining maintenance repair parts requirements for both equipment and spares for stock, but it provides that only the parts peculiar be furnished as spares on new equipment contracts. Previous to the adoption of this specification, both common and peculiar parts were furnished as equipment and stock spares.

The common parts are now being procured by ESO under separate contracts direct from the parts manufacturer. Under the new BuShips Electronic Maintenance Repair Parts Program, these common parts required for maintenance purposes will be group stocked aboard when the ship is converted.

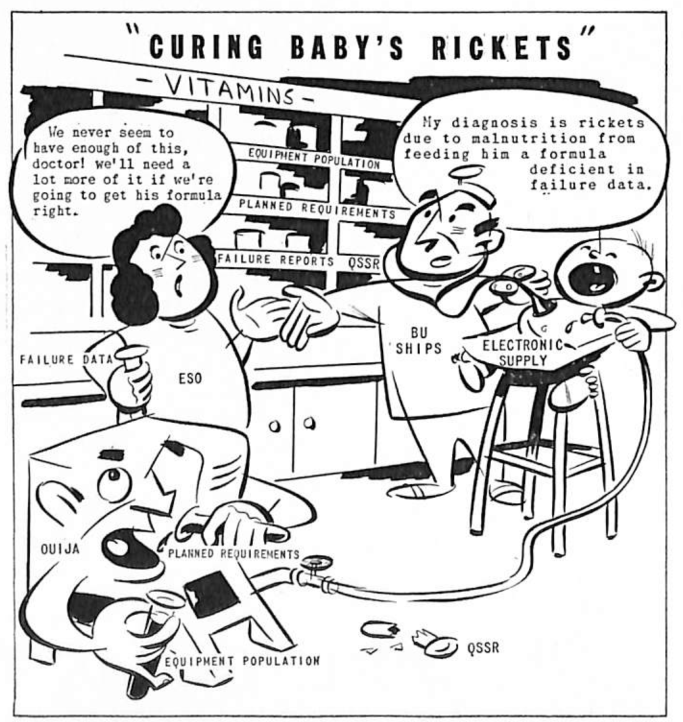
At the time new equipments are delivered, one set of equipment parts peculiar spares (now called Maintenance Parts Kit) will be provided with each equipment. The spare parts peculiar for stock will be shipped to supply activities to be binned immediately upon receipt and issued as individual items as required.

BREAKDOWN PROGRAM CONTINUED

Continuance of the Breakdown Program at the NSD, Bayonne, and SSD, NSC, Oakland, as well as initiation of a breakdown project at SSD, Norfolk, has been authorized by the Bureau of Supplies and Accounts. All eligible spare parts boxes in the Pacific area are being processed at Oakland, whereas Bayonne's breakdown responsibilities will cover boxes in the northern East Coast area, and Norfolk will process those in the southern portion of the East Coast area.

The Breakdown Program is being limited to those spare parts boxes of tender, stock or extra equipment spares which are applicable to active equipments and components. Boxes related to obsolete equipments or components are excluded from the Breakdown Program, and disposition instructions for these will be requested from the Bureau of Ships. In addition to obsolete boxes, others have been declared ineligible for breakdown because of existing Bureau of Ships directives; the vast majority of these are extra equipment spare parts boxes.

The target date for processing of eligible spare parts boxes is 30 June 1951. When this objective is reached, a tremendous amount of electronic maintenance repair parts will have been identified, binned, and recorded under valid stock numbers, and reported to ESO. As a result, large amounts of material will be available for redistribution to satisfy existing needs, and procurement requirements will be lessened.



ELECTRONIC COUNTERMEASURES INFO

Model REM Dual Pan Adaptor

The Model REM Dual Panoramic Adaptor Equipment has a high voltage supply transformer, T-104, which has been failing in service. Additional information indicates an arc-over is occuring between pin 1 of socket X-125 and the transformer case which is at ground potential. This is revealed by a small burned spot near the lower right-hand corner of transformer T-104.

To eliminate the failures which are occurring due to this arc-over, the tube socket X-125 should be loosened by means of the top screws and moved away from the transformer case as much as is permitted by the size of the socket holes and then the screws should be retightened. The prongs of the socket should be bent down away from any metal parts.

This procedure may not eliminate all transformer failures. Another possible cause of failure is an arc-over between prongs of the sockets X–125 and X–124 and ground through the shield protecting the unused prongs. The points on the shield which are in close proximity to the socket prongs and prong rivets should be marked on the shield. The shield should be removed and these points cut or filed to increase the arc-over distance. The shield should then be replaced.

A modified alignment procedure and corrections to the instruction book will be distributed to the Fleet as Change #1. This change should be available in the latter part of 1950.

Model RAO–9 Radio Receiver

The Model RAO–9 Radio Receiving Equipments used in communication countermeasure installations have balanced, center tapped, audio outputs. These installations require the use of coaxial cable between equipments. To prevent the shorting of one half of the output transformer by connecting one terminal to ground or to the shield of the coaxial cable, connect the center conductor of the coaxial cable to one terminal, either terminal of the speaker output, and directly ground the shield to the case. This will permit full audio output voltage to the phone jack and one half output voltage to the accessory equipment, which is sufficient.

Interference Between Model RDC–1 and Model RBK–14 Receivers

Some of the known sources of interference to the Model RBK–14 receiver when used in the communication countermeasure installations are the local oscillator radiation and synchronizing pulse radiation of the Model RDC–1 receiver. The interference can be noted as an audio output in the headset of the Model RBK–14 receiver at a rate determined by the scanning motor of the Model RDC–1 receiver. The local oscillator interference is noted when its frequency, during scanning, is the same as the Model RBK–14 receiving frequency. The synchronizing pulse interference is noted at the time of break of the synchronizing contacts.

The interference caused by the synchronizing pulses may be reduced if not eliminated by insuring that the synchronizing contacts are not in need of repair, the choke L–107 is not defective, and the contacts are aligned according to the procedure outlined in the Model RDC–1 instruction book.

The interference caused by the oscillator radiation cannot be eliminated. It can be reduced with the use of good installation practices such as properly grounding all equipments and cables, removing any fungus-proof material from the equipments at points of metal-to-metal shielding contact, and tightening all covers and front panel knobs.

LIGHTNING DAMAGE TO PO–2M RADAR RELAY EQUIPMENT

Lightning struck the PO–2M antenna at the Naval Air Station, Key West, Florida on 11 April 1950. All of the transmission line connectors were burned. The antenna mast was lowered and the transmission line and connectors replaced. To prevent future lightning damage, a lightning rod was installed, extending three feet above the mast and the rod was connected to ground through a No. 6 copper wire.

COGNIZANCE OF ANTI-SUBMARINE ATTACK PLOTTERS

From time to time the Bureau of Ships receives correspondence relating to procurements, repair, shipment requests, etc. for Attack Plotters, Mark 1, Mod 3 and up. Attention is called to BuOrd-BuShips Joint Letter, file No. BuOrd (PLe) S67-BuShips (980) S67–(26) Serial U–980–743 of 7 June 1948 to all ships and stations which establishes the cognizance of these attack plotters under the Bureau of Ordnance. The Bureau of Ships has certain responsibilities as to components, tubes and management, subject to technical control by the Bureau of Ordnance.

New Books

The following is a list of all instruction books distributed from 26 May 1950 to 21 July 1950. The most recent previous list of instruction books distributed appears in the August 1950 issue of BuShips Electron. The key to the abbreviations listed under the heading *"Edition"* appears below.

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

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

Model	*Short Title*	*Edition*
AM-215/U	NAVSHIPS 98163	FC #1
AM-215/U	NAVSHIPS 900,995	T-1
AN/FGC-5	NAVSHIPS 91265(A)	T-1
AN/FMQ-2	NAVSHIPS 91266(A)	Comp. IB
AN/FRT-14	NAVSHIPS 91318 Vol. 1)	C
AN/FRT-14	NAVSHIPS 91318 (Vol. 2)	C
AN/MPN-1B	SHIPS 316A	Ch. 4
AN/PDR-8C	NAVSHIPS 91295	IB
AN/SRA-3	NAVSHIPS 91292	IB
AN/TPS-1B	NAVSHIPS 98156	FC #10
AN/UDR-7	NAVSHIPS 91246	IB
AN/URM-17 (XN-5)	NAVSHIPS 91326	IB
E-2/S	NAVSHIPS 91175	IB
IM-4PD	NAVSHIPS 91033(A)	Ch. 1
IM-7A/PD	NAVSHIPS 91227	T-1
LX-1	SIG M-8	
MD-115/FC	NAVSHIPS 91264	IB
MD-116/FC and MD-117/FC	NAVSHIPS 91267	IB
ME-2/U		SIG M-8
ME-6A/U	NAVSHIPS 91269	IB
MX-735/MR, MX-735A/MR, MX-736/MR	NAVSHIPS 91316	C Sup.
OS-5/U	NAVSHIPS 91188	IB
PP-380/U	NAVSHIPS 91271	IB
PU-151/U	NAVSHIPS 91226	IB
QHC	NAVSHIPS 91186	IB
SG-21/U	NAVSHIPS 91303	IB
SO-7/M - SO-7/N	NAVSHIPS 900,968	IB
SP-1M	NAVSHIPS 98174	FC #47
SR-3	NAVSHIPS 900,539	T-1, T-2, T-3
SR-6	NAVSHIPS 900,989	T-1, T-2, T-3
SS	SHIPS 335	Ch. 1
SS	SHIPS 335	Ch. 2
SS	NAVSHIPS 98119	FC #10
SS	NAVSHIPS 98142	FC #12
SU	SHIPS 313	T-1
TDZ	NAVSHIPS 98180	FC #6
TDZ	NAVSHIPS 900,809	T-1
TDZ-a	NAVSHIPS 91284	T-1
TS-98/AP		SIG M-8
TS-239A/UP	NAVSHIPS 91148	Ch. 1
TS-611/FG	NAVSHIPS 91237	IB
UN	NAVSHIPS 91261	Comp. IB
UN	NAVSHIPS 98157	FC #1
WFA-a	NAVSHIPS 98179	Addendum A to FC #12
WFA-a	NAVSHIPS 98021	Addendum B to FC #16
WFA-a	NAVSHIPS 900,448(A)	Ch 1
XEV-1	NAVSHIPS 91294	IB
X-VK	NAVSHIPS 98151	FC #3
X-VM	NAVSHIPS 91337	IB
C-549/BAR-1 and PP-410/BAR-1	NAVSHIPS 91127	IB
Type 60ABM		SIG M-8
60089		SIG M-8
Spectrophotometer	NAVSHIPS 91311	IB

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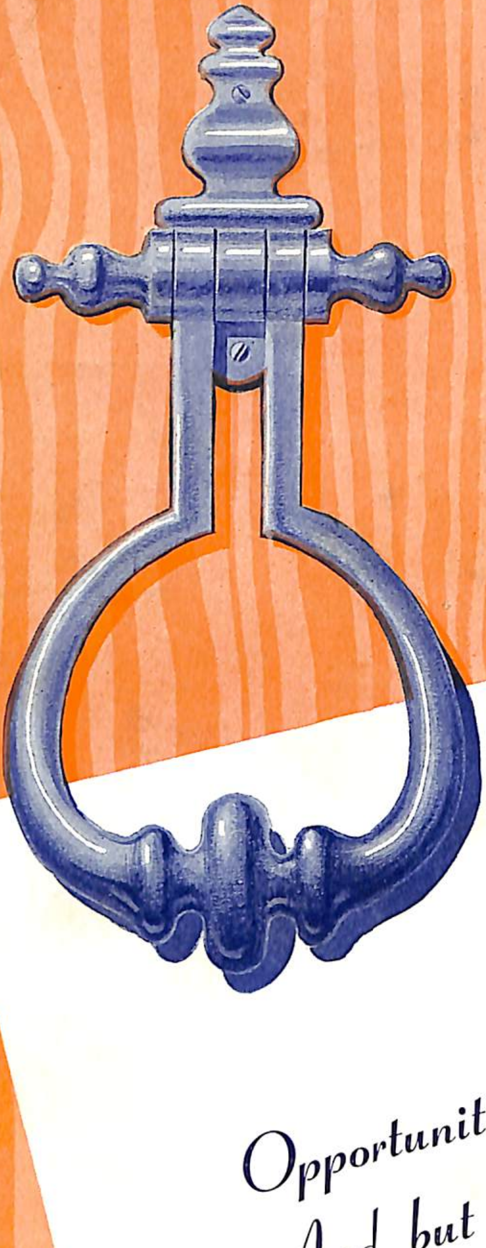
KEEP YOUR'S SHIPSHAPE



Opportunity seldom knocks,
And but once on any door.
Electronics is your opportunity,
You should use it more!!