Section 3
INTERFERENCE

SECTION 3. INTERFERENCE

RADIO INTERFERENCE ELIMINATION IN PT BOATS

The Bureau is taking action to eliminate electrical noise interference in PT boats. This is being done for two reasons—Elimination of interference with radio and electronic apparatus aboard the vessel and elimination of the possible hazard to security entailed by radiation from noisy electrical devices.

One of the worst sources of noise aboard a PT boat is the auxiliary gasoline-engine-driven generator. The interference produced is of two kinds —ignition noise and a whining noise from the generator. This latter noise is very strong and covers wide bands. All new construction boats are being furnished with generators that are free from interference. The engines are equipped with Hallett ignition shielding and a specially designed control panel which includes radio-frequency filters for the output of the generator, the oil pressure, and water temperature leads. Field tests of the system have been made on both Higgins and Elco boats, and it was found that there was no measurable ignition noise at a distance of 3 feet from the engine. The tests also indicated less than 3 microvolts of noise between ground and either of the generator output leads. It is intended to eventually furnish the Hallett shielding kit to field activities, together with an improved control panel complete with the necessary filters. This will give vessels now in service the same effective shielding employed in new construction boats.

Recent reports from the field indicate that radio-frequency noise is being produced by the motor-generator for the flux gate compass. This may be eliminated by connecting two 0.25- or 0.5-mfd. condensers in series across the 24-volt line to the motor. The junction between the condensers should be connected to the *motor frame* by a *short* wire. Suitable condensers are type RLO 4225, Cornell Dubilier DB 4025 or equivalent metal cased "bathtub" type.

The Bureau is interested in receiving reports from the forces afloat on the noise problem and remedial measures taken. They should be addressed to the attention of Code 981D.

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RADIO SHIELDING OF GASOLINE ENGINES

A considerable number of gasoline engines are in use in the fleet as prime movers for boats, electric generators, etc. Each one of these engines is a potential source of radio noise which not only interferes with radio reception but also may be a hazard to security by providing a signal for enemy location apparatus.

The Bureau, in connection with the Hallett Mfg. Co. of Inglewood, California, has developed a system of radio shielding for gasoline engines which will reduce the radio-frequency noise field to a strength of the order of two microvolts per meter measured at a distance of three feet from the engine at all frequencies between 150 kc and 20 mc. The system includes:

(1) Shielded spark plugs (aircraft type) or a metal shield for existing plugs.

(2) Breeze tube shielding for all high tension leads.

(3) A cast duralumin shield for the distributor.

(4) A cast duralumin box, enclosing the ignition coil and a radio-frequency filter for the low tension leads.

(5) Shielding for the low tension leads between the distributor and coil.

(6) Suitable fittings for connecting all shielded wires to the boxes.

(7) A ventilating system for circulating air through the shielding system.

A supplemental system has been developed which effectively eliminates electrical interference produced by auxiliary generators attached to gasoline engines. This system consists of:

(1) A cast duralumin cover for exposed generator terminals.

(2) A cast duralumin box, enclosing the volt-

age and current regulator and a radio-frequency filter for the generator output lead.

(3) Shielded wires for the output and field connections between the generator and regulator.

(4) Suitable fittings for connecting the shielded wires to the boxes.

A typical shielding installation is shown in the accompanying photographs. Figure 1 shows the spark plug shields, shielded high tension and low tension wires, distributor shield and coil shield box with filter. The copper tube extending around the rear of the motor block connects to the air intake of the carburetor; this provides a vacuum in the shielding system, drawing air in through a tiny hole in each spark plug shield. The system is ventilated to prevent the collection of ozone in the distributor; ozone attacks insulating material causing rapid deterioration. Figure 2 shows the filtering system applied to an auxiliary generator attached to the engine. The filtered low tension wire from the coil, as well as the output of the auxiliary generator, are not shielded. Shielding of these wires is not required as the noise is effectively "bottled up" inside the shielding system.

Gasoline engines now under procurement are being equipped with Hallett shielding kits at the factory. Kits are available in stock at a few Naval activities, and kits are under procurement for certain other engines, known to be "noise makers". A good example of this is the Capitol engine used on PT boats to drive an auxiliary generator. A Hallett kit is under procurement which in recent tests completely eliminated all radio noise interference from the engine. The kit also improves the engine installation, as the coil-to-distributor high tension lead is shortened from 84″ to about 12″.

The Bureau desires to know of interference produced by gasoline engines. It is prepared to render engineering service to all Naval activities and ships that are available having interference problems, and can arrange to supply shielding kits for any gasoline engine. The following data should be forwarded:

(1) Make of engine
(2) Model (if known)
(3) Serial number
(4) Contract number (if known)
(5) Any other pertinent nameplate data
(6) Photograph (if available)

All correspondence concerning radio interference should be addressed to the attention of Code 981D.

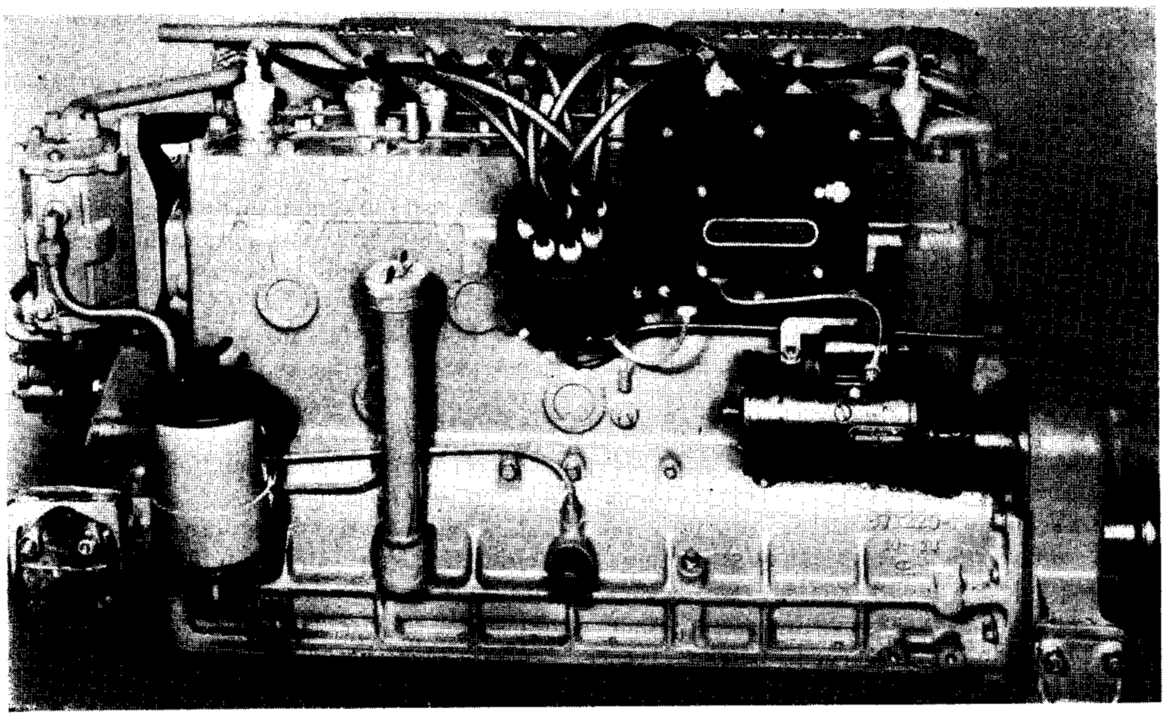

FIGURE 1.—Typical shielding installation.

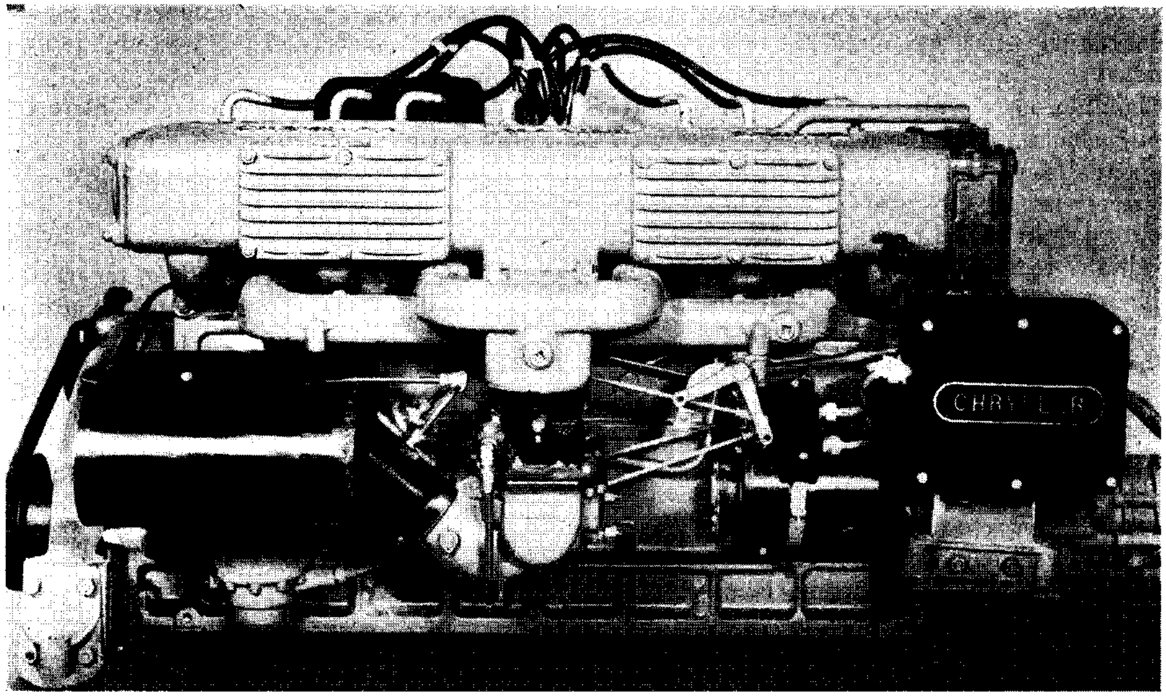

FIGURE 2.—Another view of the installation of Figure 1.

The following should be emphasized:

(1) Radio noise from gasoline engines and other devices is *unnecessary* and *can be eliminated.*

(2) The Bureau is prepared to help upon request. Action cannot be taken unless the situation is made known.

(3) The proper interference filters cause no damage to apparatus. They only eliminate the noise.

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LOCAL NOISE REDUCTION AT AIR CONTROL TOWERS

Among the many services which are rendered by the Radio Section of the Electronic Field Service Group is that of investigating field problems for Naval shore radio stations and taking the necessary steps to remedy any undesirable operating conditions.

In response to a request from the RMO for assistance in determining the cause of an excessively high noise level in the control tower receivers at NAS, Pensacola, Florida, two EFSG engineers reported to that activity.

Since the problem of excessive "man-made" noise is encountered at many activities, an account of the procedure followed to determine the source of the noise and the remedial measures taken to correct the condition may prove of general interest and value to radio shore stations.

First, a thorough examination was made of the hangar in which the control tower was located and the surrounding buildings and terrain, including a survey of the location of the receiving antennas. The control tower was found to contain three Navy model RDE receivers and one each of the Navy model RAS, RAS-2 and RAW receivers.

A spare RDE receiver, tuned to 6210 kc, was converted for operation from a dynamotor and storage battery supply in order to make comparative noise tests against the a-c operated RDE on the same frequency. From the results of these tests it was determined that the noise level was three times as great on the a-c operated receiver, indicating that an appreciable amount of noise reached the receivers through the power line.

A half-wave doublet antenna, cut to 6210 kc, was fabricated and strung from as many locations and angles on the roof of the hangar as existing facilities permitted. Noise level measurements were made on the output of an RDE tuned to 6210 kc for each antenna location to determine the position which produced the lowest noise level.

Simultaneously with these steps taken to reduce the noise, tests were conducted to determine the actual source of the excessive noise reaching the receivers. A Navy type OF noise interference locator was employed to conduct noise level tests in all the rooms in the control tower building against all electrical apparatus present. Tabulated results proved conclusively that no electrical equipment in that building radiated sufficient noise to impair radio reception in the control tower.

The noise tests were then continued outside the building. By means of the OF and the audio output of an RDE receiver modified for portable use, the noise was eventually traced to five Class 2000 National cash registers located in the ship's store building, about two hundred and fifty yards from the receivers and antennas. A thorough inspection of the electrical components of these machines disclosed the fact that three of the five motor commutators were worn, burned and pitted.

After turning down three commutators and installing new brush holders and brushes as required, all the electrical contacts, including speed regulator slip rings, were cleaned and burnished and grounds were installed on all five machines.

Before this work was performed, the noise radiated at 60 feet, due to random operation of the cash registers, reached 2000 mv on peaks.

The following table shows the change in noise radiated before and after the above work was performed on the cash registers:

	Condition A [1] *mv*	*Condition B* [2] *mv*	*Condition C* [3] *mv*
Machine #1....	2,000	1,000	50
Machine #2....	10,000	5,000	50
Machine #3....	15,000	8,000	400
Machine #4....	10,000	6,000	350
Machine #5....	2,000	800	25

[1] Original noise radiated at two feet from registers.
[2] After all commutators were cleaned and those on machines #2, 3 & 4 were turned down.
[3] After .25-mfd. bypass condensers with permanent grounds were attached to machines.

Additional tests on the noise radiation due to simultaneous operation of all machines gave the following results: at eight feet, 80 mv of noise; at fifty feet, three mv of noise; at sixty feet, no noise.

The following recommendations were made to insure the permanence of the noise-free radio reception:

(1) Incorporation in the design of the receiver console being fabricated of:

- (a) Separate acoustical speaker baffles, designed to accentuate highs.
- (b) Inclusion of a-c line filters.
- (c) Inclusion of frequency meter (LM or equivalent) to enable the expeditious checking of variable frequency receivers.
- (d) Inclusion of visual indicator on all speakers to indicate the presence of a signal.

(2) Permanent installation of the doublet antenna at location deemed best by tests performed.

(3) Installation of ground wire to topside of control tower.

(4) Establishment of system for periodic checking of noise emitted both from ship's store cash registers and fluorescent lighting fixtures in the hangar.

(5) Procurement and installation of fluorescent light radio interference filters for all fixtures in control tower building.

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ELIMINATION OF RADAR INTERFERENCE

From time to time the Bureau receives reports of interference produced in radio receivers by the use of radar apparatus. The interference manifests itself as a raucous hum or whine which covers broad bands of frequencies, especially below 500 kc. The intensity is subject to wide variations and may vary as the radar antenna is trained.

The interference enters the radio by three routes —the antenna, the power line, and direct pickup by phone cords or through the case of the receiver. The method of entrance may be determined by removing the antenna connection and noting any change in the interference level. If no change is noted, it is probable that the interference is entering through the power line or if the receiver is located near radar apparatus it is possible that direct pick-up is responsible.

Certain modifications to the radar apparatus can be made and these are helpful in reducing direct pick-up and transmission through power lines. Details of these modifications may be found in the Radar Maintenance Bulletin and other radar publications.

In most cases where the radio and radar apparatus are not in the same compartment the interference will be found to be entering the radio receiver by way of the antenna. In order to eliminate the interference, the Bureau and the Naval Research Laboratory have developed the type 53153 interference filter. This filter is shown in Figure 1 and has been found to be

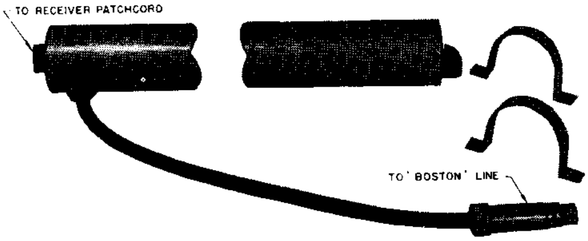

FIGURE 1.—Type 53153 interference filter assembly.

highly effective in eliminating interference produced by models SA, SC, and SK radars, or other radars in the same frequency band. The filter operates as a resonant circuit short-circuiting the radar frequency to ground. There is no effect on signals in the communications band.

The type 53153 interference filter is installed in a convenient location near where the receiver coaxial patchcords plug into the "Boston" line junction box. It is desirable to locate the unit as near to the antenna as possible. Two straps are supplied with each filter for assistance in mounting. It may be placed in any position, but should be so arranged that the ends are accessible. Connections are made as follows:

(1) Remove coaxial patchcord from the "Boston" line junction box and plug it into the type 49120 jack on the end of the filter.

(2) Plug the coaxial cable attached to the filter into the jack in the junction box just vacated by the receiver patchcord. The knob on the end is rotated for minimum or no interference. No other adjustments are required and the filter should normally require no readjustment unless the radar frequency is changed. Due to the high "Q" of the resonant circuit, the attenuation is much more than that required for most cases of interference and for this reason the knob adjustment may be "broad", i.e. there will be several degrees of rotation over which no interference is heard. In such a case the dial settings where the interference disappears can be noted and the knob set midway between them.

The type 53153 interference filter was procured under contract NXsr-55692 and is available from the New York and Mare Island Navy Yards through regular supply channels.

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RADIO INTERFERENCE ELIMINATION

Introduction

The large increase in the number and type of electro-mechanical equipments being installed aboard ships, together with the ever increasing number and type of radio and radar installations has resulted in a demand for the elimination of any radio interference produced by these equipments. The interference may not only restrict or prevent vital communications but may also divulge the position of a task unit to the enemy during periods of radio silence.

The Bureau of Ships has instituted a program for the elimination of this interference, and to this end has nominated a committee, composed of representatives of the various sections concerned, to study the problem, correlate the activities of the different groups, cooperate with equipment contractors, and furnish pertinent information on the subject to Naval ship and shore establishments.

It is planned that information will appear in this bulletin on the following subjects:

(1) Locating the Source of Interference.
(2) Radio Noise Measurements.
(3) Radio Noise Meters.
(4) General Rules for Radio Noise Suppression.
(5) Eliminating Interference from Small Motors and Generators.
(6) Eliminating Interference from Large Motors and Generators.
(7) Eliminating Interference from Ignition Systems.
(8) Eliminating Interference from Relays and Other Contact Makers.
(9) Eliminating Interference from Gas Tube Devices.
(10) Eliminating Interference from Ordnance Equipment.

(11) Eliminating Interference from Radar Equipment.
(12) Measuring Radio Noise with an Ordinary Receiver, Oscilloscope, and Signal Generator.
(13) Design of Screened Rooms.
(14) Attenuation Measurements.

A knowledge of the fundamentals underlying the above subjects should enable the military and civilian personnel of the Navy to better cope with interference problems arising under their jurisdiction. The Bureau hopes to receive comments on these articles, and is also desirous of receiving reports on cases of interference including remedial measures taken and the results therefrom. Address all relative communications to the Bureau of Ships, Code 925A.

Locating the Source of Interference

To determine whether the noise is internal or external to the receiver, proceed as follows: If the interference is being introduced into the receiver through the antenna system, it will disappear or at least be greatly reduced if the antenna is disconnected at the receiver input terminals or if the input terminals are short-circuited. This naturally has no effect on noise arriving through the power line or being generated in the receiver itself except for internal noise that requires cross modulation of a carrier to make itself evident. This test is important when the interference sounds similar to tube noise or power supply hum. Care must be exercised in using this method with receivers designed for the higher frequencies since a short length of antenna lead or unshielded circuit may be sufficient to pick up large amounts of interference when the source is close to the receiver.

Having determined that the interference is being picked up by the antenna, it is then necessary to determine the exact source. One of the most effective methods is to turn off all equipment that is operating in the vicinity; if the interference stops, each individual equipment may then be turned on, one at a time, and the results noted. It is better to start with all equipments off rather than stopping individual equipments when all the others are operating because there is a possibility of one source being masked by other sources. A record of the time that the interference starts and stops is often of great help in spotting the offending equipment.

It is not always convenient to have all equipments turned off. An experienced investigator can often identify the source by the nature of the sound heard in the headphones or loudspeaker. Another method sometimes used by the trained man is observing the waveform on an oscilloscope connected to the receiver output. Considerable experience is required to make the most of these methods.

Most interference surveys require the use of a portable receiver (interference locator or radio noise meter). Where a large area is involved it is often advantageous to use a loop receiver as a direction finder, and attempt to locate the interference source by triangulation. This method fails when the interference is radiated from power lines at points remote from the equipments generating the interference; neither is it of much use aboard ship.

The most common method is to carry a radio noise meter about the suspected area and observe the intensity on the indicating meter. Noise sources usually have a large gradient in their immediate vicinity and it is often possible to walk up to the source of interference by proceeding in in the direction of increasing readings.

After locating the offending equipment it is then necessary to determine what particular part of the equipment is responsible for the disturbance. This is done by a judicious use of any possible individual switches on various units of the equipment and by the use of probe antennas.

Probe antennas can be obtained (or made) in the form of small loops for magnetic pickup or a length of shielded cable with about 5 inches of the insulated inner conductor extending beyond the shield for electric pickup. The shield covering the leads to the probes should be connected to the case of the noise meter. Such small insensitive antennas will be effective only when they are brought up very close to the source and thus are of great aid in locating the actual source.

In order to give some idea of the number and character of the possible sources of interference on board Naval vessels a partial list is given here:

Main generators.	Line control apparatus.
Driving motors.	Radar equipment.
Oil pump motors.	Sonar equipment.
Water pump motors.	Pitometer logs.
Air compressor motors.	Gyro equipment.
Fan and blower motors.	Winch motors.
Refrigeration motors.	Rotating shafts.

Steering motors.
Calculating machines.
Shaft revolution counters.
Communication motor-generators.
Laundry equipment.
Machine shop.
Transmitter keying systems.
Inter-radio sounder circuits.
Teletype equipment.
Soda fountain mixers.
Galley equipment.
Barber shop equipment.
Medical and dental equipment.
Searchlight circuits.
Buzzer systems.
Fire alarms.
Telephone equipment.
Gunnery signal circuits.
Dead reckoning tracers.
Boiler feed signal system.
Lubricating oil low pressure alarms.
Telephone systems.
Radiating receivers.
Sound powered telephones.
Air lock belts.
Ventilation motor warning signals.
Oil burner telegraph systems.
Arcing incandescent lamps.
Auto-pulse fuel pumps.
Portable electric drills.
Arc welders.
Battery chargers.
Code practice equipment.
Fluorescent lamps.
Driving belts.
Electric typewriters.

In general:

All motors and generators.
All vibrating electrical contacts.
All gas tube rectifiers.
All poor electrical contacts.

All the items in the above list are not necessarily trouble makers but they are potentially so. Even equipment that normally does not create interference may do so when defective or in bad condition. It is possible that many large sources are located below decks in such a way that they do not couple into the receiving systems. However, they are still to be given consideration since the installation of wires or cables, for any purpose, that lead out of a compartment may pickup and re-radiate interference that will be quite troublesome.

Radio Noise Measurements

Interfering disturbances may have a waveform of almost any character from simple sine waves to highly complicated shapes. The interfering effect of noise (at least its effect on the human ear) is usually considered to be proportional to its peak value. In order for an apparatus to indicate peak or quasi-peak values, consideration must be given to the following factors:

(1) Bandwidth of the receiver.
(2) Time constant of the integrating circuit.
(3) Indicating meter constants.
(4) Method of calibration.
(5) Type and size of pickup antenna.
(6) Method of use.

Only the first of these factors, the bandwidth of the receiver, applies to the instrument affected by the noise. The other factors are inherent in the design of measuring equipment and will be considered in a later article on the subject of radio noise meters.

It is convenient to classify noise into two types, namely, *random* and *impulse*. Various combinations of the two types may be encountered.

Random noise is that due to the aggregate of a large number of elementary disturbances with random relative phases and with its energy not confined to a narrow band in the frequency spectrum. Noise from motors, generators, continuous arcs, etc., usually fall within this classification.

Impulse noise is that due to a single elementary disturbance or to an aggregate of elementary disturbances with systematic relative phases and with its energy not confined to a narrow band in the frequency spectrum. It is a disturbance having an abrupt change and short duration or a succession of such disturbances. Ignition noise and other pulsed characters are of this type.

It has been found that the peak, effective, and average values of random noise are directly proportional to the square root of the bandwith of the receiver. For impulse noise, the peak value is directly proportional to the bandwidth, the effective value is directly proportional to the square root of the bandwidth, and the average value is independent of bandwidth. These relationships hold only for noise spectrums that are uniform over the receiver bandwidth. The ratio of the peak value to the effective value or the peak value to the average value varies greatly with the type of noise. It is usually very high for impulses; the lower the repetition rate, the higher the ratio.

To measure the bandwidth of a receiver for the purpose of comparing interference values, the ratio of the voltage input at resonance to the voltage input off resonance needed to give the same output is squared and plotted on linear graph paper; the effective bandwidth then corresponds to the ratio of the integrated area under this curve to the area corresponding to a rectangle one kilocycle wide which has a height equal to the maximum response of the receiver. In general, this value will differ from the conventional bandwidth value found by taking the half energy points.

In accordance with the above considerations, it is then possible to state the interference level in microvolts for a *one*-kilocycle bandwidth (not microvolts per kilocycle). As pointed out at the beginning of this article the absolute determination of noise level involves many factors that make it difficult to accomplish with portable equipment. For this reason, certain compromises are necessary. Portable noise meters are available which are built to certain standard specifications and which indicate quasi-peak values which are more or less representative and duplicative when the equipments are properly used. These standard noise meters and their use will form the subject of the next section of this article.

Radio Noise Meters

A radio noise meter is essentially a sensitive portable receiver capable of measuring noise levels and field strength. It may be used as a radio-frequency voltmeter to measure voltage between two points, or when equipped with a ship antenna it will measure the strength of a radiated field. It differs from a convential receiver, however, in several important respects. A time delay is introduced in the AVC circuit so that the output meter will measure the quasi-peak value of the noise since this value is more significant than the average. This circuit is known as the detector weighting circuit. Further, the receiver gain must be adjusted to previously calibrated levels in order that measurements will be uniform for all frequencies. A calibrating signal source is included in the equipment for this purpose. There is also an input attenuator to increase the range of the equipment.

A block diagram of a typical noise meter is shown in Figure 1. The single meter shown in

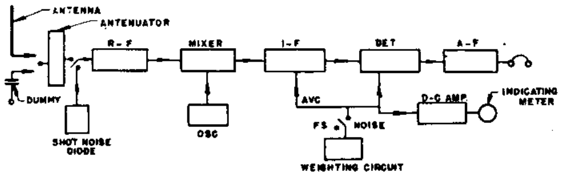

FIGURE 1.—Block diagram of a typical noise meter.

this figure serves to measure the battery voltages, adjust the calibrating diode current, set the calibration control and read the value of the noise or signal intensity.

On page INT:7 it was pointed out that noise measurements depended, among other factors, upon the time constant of the integrating circuit (detector weighting circuit), the indicating meter constants, the calibrating circuit, the type and size of the antenna, and the receiver bandwidth. These considerations have been standardized by specifications issued by the Joint Coordination Committee on Radio Reception of the Edison Electric Institute, the National Electrical Manufacturers Association and the Radio Manufacturers Association. These specifications apply to equipments covering a range of 150 to 350 kilocycles and 540 kilocycles to 18 megacycles. (The interval between 350 and 540 kc is provided to accommodate the intermediate frequencies of the meters). The Navy has established specifications and the following significant excerpts are quoted:

(1) The instrument shall have a collapsible vertical rod antenna not exceeding 7 feet in length.

(2) The weighting detector circuit shall have a charge time constant of 10 milliseconds ($\pm 20\%$) and a discharge time constant of 600 milliseconds ($\pm 20\%$). The time constant of the unweighted AVC circuit shall be short compared with that of the weighting circuit.

(3) The indicating meter shall have a damping factor of not less than 10 nor more than 100. It shall have a time constant of not less than 200 milliseconds nor greater than 500 milliseconds.

(4) The receiver bandwidth shall be between 8 and 10 kilocycles.

(5) The self-contained calibrating signal source shall be calibrated in terms of a sine wave standard, and shall be capable of maintaining the accuracy of the radio noise meter to within $\pm$ 15% in the frequency range of 540 to 1600 kc. The accuracy at all other frequencies shall be within $\pm 15\%$.

The following equipments have been built around these specifications:

Ferris model 32A or Navy model OF.
Ferris model 32B or Navy model OF–3.
RCA model 312A and RCA model 312B
Navy model OF–1 (modified) and Navy model OF–2.

It has been pointed out that in order to obtain comparable noise measurements, the receiver gain of the meter must be set at a predetermined level in accordance with the frequency of the noise being measured. A standard noise source is provided for this purpose and is built into the equipment. It consists of a diode (or diode-connected) vacuum tube operating at saturation. The shot noise of the tube when operating at saturation provides a sufficiently constant source of noise for calibration purposes. To maintain the space current at saturation a filament rheostat is provided.

In general, the procedure for calibrating the instrument is as follows: A standard signal generator is connected to the antenna terminal through a dummy antenna equal in capacity to that of the antenna normally used with the equipment. This dummy should be located directly at the antenna terminal. The output of the signal generator is adjusted to supply a given input to the noise meter (e.g. 100 microvolts) and the noise meter is then tuned to the signal generator frequency and its gain adjusted to produce this reading on the indicating instrument. The signal generator is then cut off and the output of the calibrating diode is connected across the first tuned circuit (by means of a switch on the panel —"Cal Pos"). The meter reading now gives the calibration setting for the particular frequency being used. The instrument should be calibrated for a series of frequencies on each band and a calibration curve plotted.

To calibrate the instrument with the internal calibrator, it is then only necessary to turn the switch to "Cal Pos", and adjust the gain control until the meter reads the calibration value as determined above. The instructions that accompany each equipment should, however, be followed in detail. One company produces an "External Calibrator" which can be fastened on the noise meter. It is essentially a signal generator covering the same range of frequencies as the noise meter with an output adjustable to 1000 microvolts. It is more accurate than the internal calibrator and not as bulky as a regular signal generator.

In order to provide sufficient gain for calibrating the meter at all frequencies and to obtain correct meter scale over the range of the indicating instrument, it is usually necessary to use specially selected tubes in the r-f and i-f positions. It may also be impossible to obtain correct calibration if the battery voltages are too low. These instruments require extreme care and careful maintenance in order that they shall give reliable service. Realignment and recalibration are necessary at frequent intervals if the equipments are often transported from place to place.

In the frequency range of 15 mc to 150 mc, there is at present only one suitable equipment available: the Measurements model 58. This equipment follows the same general pattern as the lower frequency type except that it is arranged for a low-impedance line input and can be used either with dipole or loop antennas. The bandwidth of the receiver is approximately ten times that of the lower frequency equipments. Since both the bandwidth and type of antenna affect the reading which will be obtained on noise fields measured near the source, it is necessary to use care in interpreting the results obtained. This equipment operates from a built-in combination 115-volt a-c and 6-volt d-c vibrator power supply.

It can be seen that a noise meter is essentially a radio-frequency voltmeter with a special time-constant-weighting circuit. It can be used either to measure the voltage between two points, such as across a line, or the voltage developed in an antenna. When used as a two-terminal voltmeter, some types of equipments require a dummy antenna placed at and in series with the antenna terminal. This dummy is a condenser having a capacity equal to that of the antenna normally used with the equipment and is necessary in order that the tuning of the first tuned circuit does not change when connecting the instrument across lines. In some equipments the first tuned circuit is not affected and it is possible to calibrate and use the equipment without the dummy for conducted measurements. The instrument requires two calibrations in the former case, one with the dummy for antenna measurements and one without the dummy for conducted measurements. The instruction book accompanying each instrument will describe the correct procedure.

If measurements are being made on high-voltage lines, it is also desirable to use series blocking condensers of about 0.01-microfarad capacity between the instrument and the line to keep the line voltage off the instrument. Measurements made on lines are referred to as *conducted measurements* and the noise voltage so measured is called the *conducted voltage* or the radio-influency-voltage (R.I.V.). The term derives from the distinction of voltages on the line due to sources at radio frequencies as opposed to voltages at power frequencies. The value of the voltage thus measured will depend upon the impedance across which the voltage is measured. This varies from a few ohms to several hundred ohms, depending upon the characteristics of the line and the load. In many cases of interference investigation, it is immaterial what the value of this impedance is. However, if measurements are being taken for the purpose of comparing different interference producing equipments that may operate under different load and line characteristics, it becomes necessary to specify the conditions of measurement.

Radiation measurements are usually made at a specified distance from the source and with the antenna normally supplied with the outfit. The antennas for the lower frequency equipments are designed to have an effective height of either one meter (79″ in length) or one-half meter (41″ in length). The reading of the indicating instrument must be divided by the effective height of the antenna used to obtain the field strength in microvolts per meter. The effective height of loop antennas or adjustable dipoles varies with frequency. A table or graph is supplied with these antennas giving the values of effective height for all frequencies within range of the equipment with which they are used. Sometimes these values are converted to multiplying factors to facilitate computation of field strengths.

Electromagnetic Fields

There are two components to the field set up by a source of interference; one called the electric and the other the magnetic. At distances of several wavelengths or more from the source, the fields are in time phase and space quadrature with each other. They bear a definite relation to each other and either may be used for measurements of the field intensity. They are related by the equation $E = 300\ H$, where "E" is the electric field intensity measured in volts per centimeter and "H" is the magnetic field intensity in lines per square centimeter (Gauss). An electric field intensity of 2 millivolts per meter would induce a voltage of 6 millivolts in an antenna of 3 meters effective height. The antenna is to be oriented for maximum pickup, that is, parallel to the electric lines of force. The direction of the electric lines is referred to as the direction of polarization of the wave.

Since the above relationship for the electric and magnetic fields is considered to hold at distances greater than one wavelength from the radiator, measurements made on the magnetic field by using a loop receiving antenna can and usually are given in volts per meter or some submultiple, such as millivolts or microvolts per meter. Magnetic units are seldom employed in practice.

The relation between the electric and magnetic fields discussed above does not, in general, hold in the immediate vicinity of the radiating source. In this area, measurements made on the electric field may give values larger or smaller than measurements made on the magnetic field, depending on the type and configuration of the radiator. This is an important point because it partially explains discrepancies between measurements made with noise meters using different types of pickup antennas.

Important also is the fact that near the source the electric field's strength decreases inversely with the square of the distance, while at distances greater than about one wavelength it decreases inversely with the first power of the distance, neglecting ground attenuation and any reflection of the wave from any of the various possible reflecting surfaces such as hills, buildings or the Heaviside layer.

Because of these differences in the nature of the field at different distances from the source, it is convenient to divide the field into two parts, namely, that part near the radiator which is called the *induction* field and that part more remote from the radiator which is called the *radiation* field. At distances equal to the wavelength divided by 2 pi, the two fields are equal. The radiation field is sometimes thought of as the field that leaves the radiator never to return (unless reflected back) while the induction field is the field that stays at home. Either field will induce voltage in an antenna. The term "radiated measurement" is used in interference work regardless of how far away from the source the interference is measured.

The amount of interference produced in a certain piece of equipment by any given source will depend upon three factors. They are sometimes referred to as the influence factor, the coupling factor, and the susceptibility factor. The influence factor is determined by the amount of power radiated and the bandwidth or spectrum of the radiation. The coupling factor is governed by the physical separation of the source and receiver, the frequency separation and the nature of the intervening mediums. The susceptibility factor is a function of the type of equipment used in the receiving installation.

Interference usually originates at some point source, such as motor brushes, vibrating contacts, etc. In order to radiate much power, this source must be more or less efficiently coupled to some radiator such as connecting wires or the mass of the machine. Point sources, in themselves, may be troublesome at very close range but they are usually coupled to more efficient radiating mediums. Interference has been known to travel for miles over power lines and may actually be of greater intensity at a point remote from the source than near the source itself. Another important radiator not to be overlooked is any current path formed by multiple grounds. In general, it may be said that the source must be shielded, the connecting lines filtered near the source, and ground loops avoided. More will be said about this later.

When is interference suppression necessary? In general, it may be said that suppression is required on any equipment that is a potential source of interference if there is any possibility of any detectable radiation from that source external to the ship's hull or within the hull in such a manner as to couple to any leads that may in turn couple to some portion of a receiving system. In practice some compromise between cost (and perhaps bulkiness and weight) of the suppression devices and the complete suppression of the interference may be necessary. The question of limits will be discussed later

General Rules for Interference Suppression

Maintenance of Equipment.—Experience has shown that there is often a definite relation between the mechanical condition of the equipment and the radio noise output resulting therefrom. This is particularly true of rotating and vibrating machinery. All commutators, slip rings, brushes and brush holders must be kept in good condition. All normal ground connections to the frame or housing should be kept clean and tight. Movable contacts such as switch points, relay contacts, etc., should be clean and adjusted for minimum arcing. All shielded connections and bonding must make clean and tight electrical contact. A very frequent source of trouble is that caused by painted contact surfaces instead of clean metal-to-metal contact.

Direct radiation or induction from a source of interference is elminated by proper shielding and bonding. Naval equipment should be designed and installed with this in mind. Wherever possible, all leads, both power and control, should be run in shielded cable. In some cases double shielded cable is required. All cover plates must fit tightly and make good electrical contact *along the entire edge*. Solid metal is the best form of shield but copper mesh or hardware cloth is effective and can be used where ventilation is required. Bonding between units should be done with large size conductors and the lengths should be kept to a minimum.

The cardinal principle in good shielding is that current shall not be permitted to flow on the outside surface of the shield. If it does, radiation will take place. This principle can best be illustrated by reference to Figures 2 and 3 in which a load is connected to a high frequency generator by means of a shielded cable. In Figure 2, the

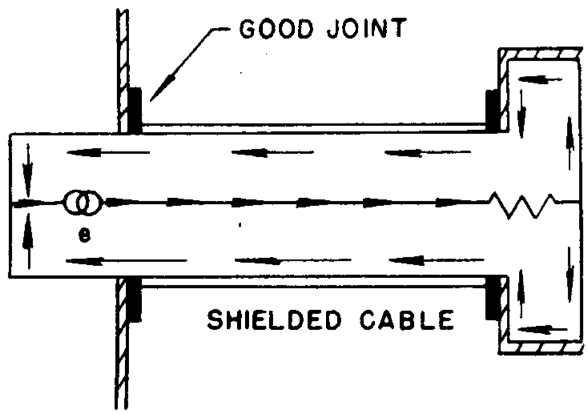

Figure 2.—Good shielding.

cable is joined to the two units by suitable coupling units which insure clean and tight electrical contact around the whole periphery of the end of the cable. In this case the high frequency currents are confined to the interior surface of the shielded system as shown by the arrows.

In Figure 3 a poor joint, possibly caused by a dirty or poorly fitting mating surface, allows current to get out to the exterior surface thereby allowing radiation to occur. This is a practical example that is very frequently found in practice.

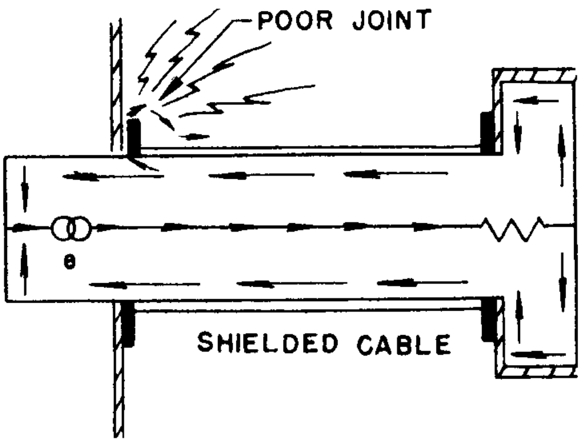

FIGURE 3.—Bad shielding.

Numerous cases have occurred where an additional quarter-turn of a coupling nut on an ignition cable has meant the difference between a "quiet" system and one that could not be tolerated. It should be pointed out here that longitudinal breaks in a cable are far less serious than transverse breaks.

FILTERING.—The type of filter to be applied to a source of interference is governed by the type of disturbance, the characteristics of the circuits, the voltage, the current, the power frequency, the amount of attenuation desired, and the frequency range to be suppressed. In all cases, the filter should be mounted as close to the actual source as conditions permit and should be shielded. The output leads of the filter must be kept segregated from the input leads since any capacitive coupling around the filter will destroy its effectiveness. Simple capacitor filters are effective over limited ranges of frequencies if their reactances at these frequencies are low compared with the impedance of the line or device into which the filter is to work. Wide band attenuation demands that well designed choke-condenser filters be used. In any case, the lead length must be kept short in order to keep the inductance low.

It is not the purpose of these articles to discuss the mathematical design of filters but to indicate the requirements of a good filter from a practical standpoint and to give a few pointers on the proper installation technique. A typical problem is illustrated in Figure 4 in which a d-c generator is supplying plate voltage to a receiver through a power cable.

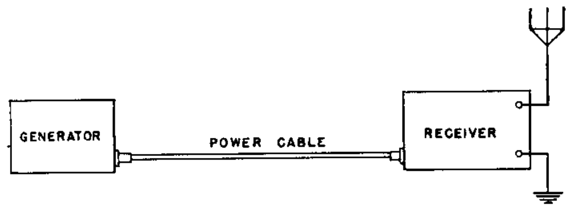

FIGURE 4.—Shielding problem.

There are three ways by which interference voltage from the commutator of the generator may reach the receiver circuits in such a manner as to produce noise in the output.

(1) Radiation from the source and lines to the antenna.

(2) Induction from the "noisy" lines inside of the receiver into the tuned circuits.

(3) Modulation of the plate currents of the various tubes in the receiver due to the interference voltages in the supply lines.

The effect of (1) may be eliminated by adequate shielding of the source and lines. That of (2) may be eliminated by careful shielding and compartmenting within the receiver. To eliminate (3) requires filtering at the source of the receiver. When filtered at the source, the shielding requirements are somewhat less rigid.

Filters

Where interference is to be eliminated at the source by the use of filters, it is necessary to decide on the type to be used.

Figure 5 shows a condenser connected across the terminals of a generator. The purpose of the condenser is to provide a low impedance path between the terminals for the interfering currents. The effectiveness of this device will be inversely proportional to the ratio of the impedance of the condenser to that presented by the line (and load) at the terminals. This means that reactance of the condenser (including leads) must be much lower than that presented by the line *at the lowest frequency to be suppressed.* This, in turn, means large capacity at the lower frequencies and extremely short leads at the higher frequencies.

Every condenser has a series resonant frequency determined by its capacity and inductance (the inductance may be low but never zero). Below this resonant frequency the reactance is capacitive; above, it is inductive. Large capacitors ordinarily have relatively high inductance and therefore are not suitable for the higher frequencies. Small capacitors may be made with rather low inductance but they are not effective at the lower frequencies. For this reason, two capacitors are sometimes used in parallel, a large one for the lower frequencies and a small one for the higher frequencies. Large capacitors cannot be used in places where the capacity would affect the normal operation of the equipment. Examples of this will be pointed out later.

In many cases a simple capacitor connected as shown in Figure 5 will have little, if any, effect

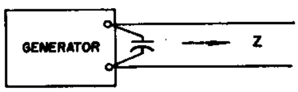

FIGURE 5.—A simple filter connected across the terminals of an interference source.

at any frequency. The reason for this is that while it may place the two sides of the line at the same r-f potential, it does not, as a rule, ground the lines for the r-f potential. Therefore, a voltage exists between the lines and ground that can affect the receiver circuits. To eliminate this effect, two condensers are used, one from each side of the line to ground, as shown in Figure 6. This

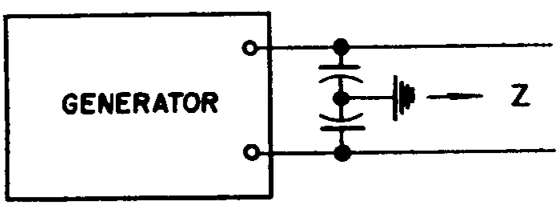

FIGURE 6.—Filter connecting both sides of interfering source to ground.

forms a low-impedance path between the lines and ground as well as across the line. This is the fundamental circuit of most of the condenser-filters in use. Figure 7 shows the same thing with a more direct return to the generator housing and is usually more effective.

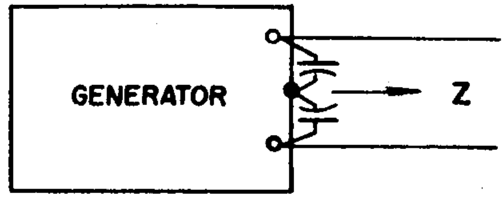

FIGURE 7.—Direct path to ground provided by grounding filter to housing of noise source.

A complete summary of the factors that influence the choice of the filter system to be applied to a given source of interference shows that consideration must be given to each of the following factors:

(1) The intensity and spectrum of the interference.

(2) The limits to which suppression is necessary or desirable.

(3) Space and weight limitations.

(4) Voltage, current, capacity, and frequency limitations.

(5) Temperature, humidity, and other climatic conditions.

(6) Costs.

Regardless of the type of filter to be used, there are certain fundamental rules that apply in all cases:

(1) The impedance of the capacitive path across the interfering source must be made low for the frequencies to be suppressed and high for the frequences to be passed.

(2) The impedance of the series inductance should be high for the frequencies to be suppressed and low for the frequencies to be passed.

(3) The filter components should be shielded and the output leads isolated from the input leads.

(4) The shield box should make good electrical and mechanical contact with the housing of the device to be filtered.

(5) The condensers and filter terminals must be able to withstand the maximum impressed voltage.

(6) The filter must carry the desired current without overheating or excessive voltage drop. If iron core material is used, saturation should be avoided.

The impedance into which a filter works should be high compared with the impedance of the filter

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itself; otherwise the filter cannot act as an effective shunt for the interference. Since this is normally not the case for a simple condenser filter over a wide band of frequencies, it becomes necessary to increase the ratio of these impedances by some means. This can be accomplished by using a series inductance as shown in Figure 8(a). Additional sections may be added as shown in Figure 8(b), and terminal condensers are frequently used as shown in Figure 8(c) or 8(d).

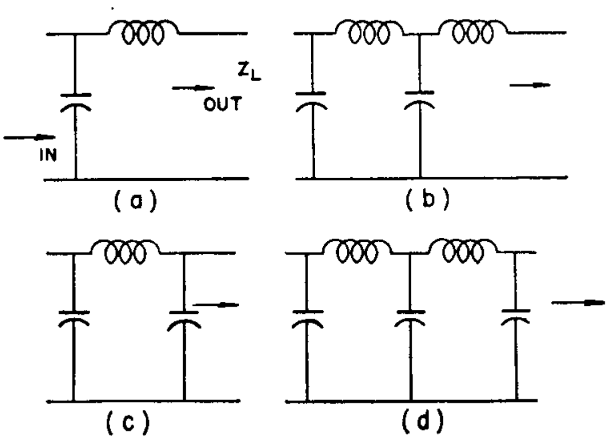

FIGURE 8.—Common LC filters with one side of line grounded.

These are common filters for use when one side of the line is grounded. If both sides are above ground, and especially where the line is balanced, equal values of inductance are inserted in series with both sides of the line as shown in Figures 9(a) and 9(b). Other forms in common use are shown in Figures 10(a) and 10(b).

The effect of poor conductivity in the filter connections is shown in Figures 11(a) and 11(b), in which the resistance in the return leads of the condensers allows the interference currents to take the capacitive path around the inductance, thus making the filter much less effective. The application of these fundamentals is essential if

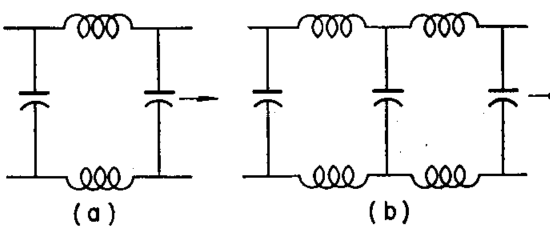

FIGURE 9.—LC filters required when both lines are above ground

good filtering is to be obtained over a wide band of frequencies.

The attenuation of filters for Naval use is usually measured for 20-ohm terminations; that is, during measurement the filter is inserted in an

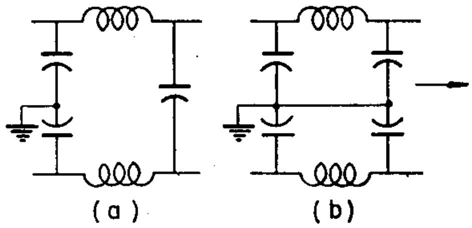

FIGURE 10.—Other common forms of LC filters.

artificial 20-ohm line under so-called *ideal* conditions in which the input and output terminals are completely shielded from each other. If the input and output terminals are not completely shielded from each other the attenuation will be less than the rated value. If the source and load impedances differ from the 20-ohm value, as is usually the case, the attenuation which will be obtained in a given installation will be higher or lower than the rated value.

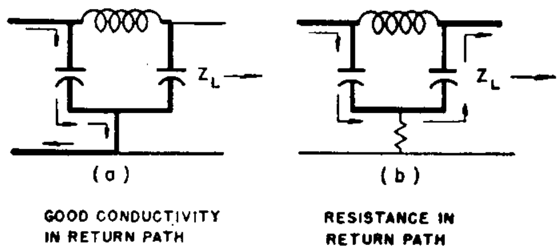

FIGURE 11.—Effect of poor conductivity in return path of filter.

The spectrum of the interference is dependent upon the type of interference source and the electrical dimensions of various parts of the installation that may act as resonant circuits and radiators. Commutator interference is usually greater at the lower frequencies but may also have peaks in the neighborhood of 20 to 50 mc. Ignition interference is more pronounced in the HF and VHF ranges. Interference from radar modulators is heaviest on the low and medium frequencies but usually goes through a large number of maxima and minima.

A number of standard Navy power-line filters have been developed to give attenuations of 60 db (voltage ratio of 1000 to 1) or better between 150 kc and 150 mc. They are listed below together with their voltage and current ratings:

Navy Type	*Voltage (volts)*	*Current (amperes)*
CTD 53171	30	15.0
CTD 53172	250	30.0
CTD 53173	30	30.0
CTD 53174	40	30.0
CTD 53175 (dual) ...	150	1.5
CTD 53176 (dual) ...	250	2.5
CTD 53177	440	100.0

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