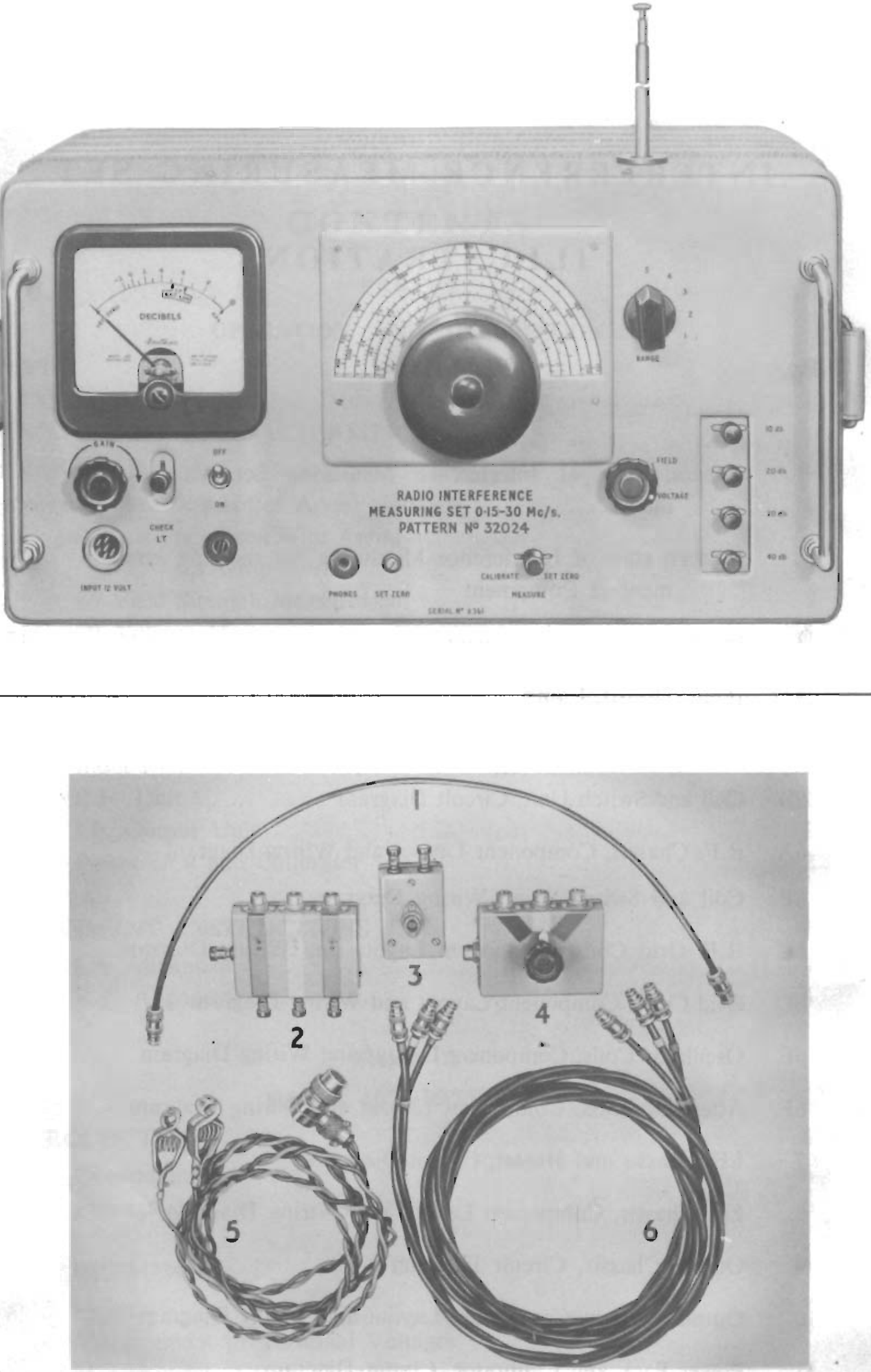

Fig. 1 The Radio Interference Measuring Set Pattern No. 32024 (upper illustration) and associated equipment (lower illustration).

(*annotations to lower illustration are referred to in INTRODUCTION on facing page*).

PART I

OPERATION AND DESCRIPTION

Introduction

The Admiralty Pattern 32024, Portable Radio Interference Measuring Set is designed for the measurement of radio frequency noise voltages and fields over the frequency range 0.15 Mc/s to 30 Mc/s. It is intended for use in the investigation and measurement of radio interference in H.M. Ships and Shore Wireless Stations. The equipment enables accurate measurements to be made of all types of interference and field strengths of radiated signals from radio transmitters.

The Measuring Set is contained in a carrying case, together with the following additional items, as shown in fig. 1, necessary to enable the different types of measurement to be carried out:

(1) Power supply lead complete with plug and spring clips for connection to battery terminals. (5 fig. 1.)

(2) Three way co-axial lead with plugs. (6 fig. 1.)

(3) Single way co-axial lead with plugs (1 fig. 1.)

(4) Three way measuring head mains connection unit for connection to two- or three- line power systems. (2 fig. 1.)

(5) Three way selector switch. (4 fig. 1.)

(6) 41″ vertical rod aerial. (Shown *in situ*, fig. 1.)

(7) Measuring Head 500/80 ohms impedance transformation unit. (3 fig. 1.)

Headphones and batteries are not supplied with the instrument but the appropriate pattern items detailed under Electrical Characteristics should be obtained from Naval Stores.

Essentially, the equipment is a high performance superheterodyne receiver, having a constant noise bandwidth. An internal pulse generator is provided for calibration and the sensitivity can be set to a constant value for all frequencies by reference to this generator. For voltage measurement, no calibration curves are necessary and, once the sensitivity of the set has been adjusted by reference to the pulse generator, signals may be measured directly in decibels above 1 micro volt by addition of the attenuator settings and meter scale indication. The meter scale is calibrated from – 2 decibels to + 10 decibels and the attenuator is adjustable in steps of 10 decibels from 0 decibels to 90 decibels.

A 41″ vertical rod aerial is provided for field strength measurements and a calibration curve is required for these measurements. Owing to the requirements for noise measurement and the high impedance at low frequencies of so small an aerial, the field sensitivity is considerably lower than the voltage sensitivity at low frequencies.

ELECTRICAL CHARACTERISTICS

Frequency Range

0.15 Mc/s to 30 Mc/s in five ranges with a gap from 410 kc/s to 550 kc/s.

Meter Range

Voltage, 1 microvolt to 0.3 volt.

Sensitivity

Field strength, 200 microvolts per metre at 200 kc/s to 15 microvolts per metre at 30 Mc/s (approx.). (Using 41″ rod aerial.)

Accuracy

±2 decibels for all signals, pulse, C.W. and "white" noise.

Headphones

A.P. W621 or equivalent impedance type are suitable.

Power Supply

D.C. 12 volts, 6 amps. A.P.14062 battery or equivalent is suitable.

Physical Details

Weight	35 lbs.
Dimensions	16½″ x 9″ x 10½″

TECHNICAL DESCRIPTION

General

In principle this set consists of:

1. A high gain constant bandwidth receiver, tunable from 150 kc/s to 30 Mc/s and of sufficient sensitivity to operate the output meter at the lowest input signal level to be measured.
2. A signal source of known output covering a similar frequency range for setting up receiver gain.
3. An input attenuator allowing a wide range of voltage or field strength measurement to be made.
4. A suitable power convertor unit, provision for aural monitoring of the signal, with switching facilities for setting, checking and general application.

A description of the circuit follows. Reference should be made to the appropriate circuit diagrams.

As the equipment consists of four internal units (fig. 2), the following description is so divided. Reference is made where necessary to units other than that being considered.

Input Unit (fig. 3)

The input impedance of the set is 80 ohms and the input socket is connected to a four step attenuator providing a total attenuation of 90 dB.

For field strength measurements the 41″ vertical extending aerial is connected by means of switch S.3 through matching transformers T1, T2 to the attenuator, the appropriate transformer being selected by switch S.1/7 which is ganged to the frequency range switch.

The attenuator output is connected to the first R.F. stage of the set through switch S.2, a three-position toggle switch, spring biased to the centre position. This permits selection of the input signal or internal calibrating signal for application to the receiver. The third switch position removes all signals thus allowing the output meter to be "Zero Set."

Contacts on switch S.2 also control the H.T. supply to the calibrator valves V.9 and V.10 (Power Unit fig. 11).

R.F. Unit (fig. 5)

Connection between the input and R.F. unit is by co-axial cable which connects Switch S.2 (fig. 6) to an intermediate frequency trap (fig. 2b) consisting of a high Q acceptor circuit, L.23, C.69 and C.70 tuned to attenuate frequencies within the I.F. pass band.

Note.—To permit easy reference to individual inductances the description of the R.F. circuit assumes that the frequency range switch is positioned as shown on the circuit diagram (*i.e.*, Range 5).

Input signals are applied to the R.F. amplifier V.12 and matched by tapped inductance L.5 which is tuned by a section of the three ganged tuning capacitors C.71. Alignment in both R.F. and oscillator circuits is by variable iron dust cored inductances and small parallel trimming capacitors, accessible when the equipment is removed from its case.

The R.F. gain is controlled by variation of the screen voltage of V.12. This control is effected by R.45, a potentiometer mounted on the power unit (fig. 5). A tuned transformer L.10 and L.11 couples V.12 to the frequency changer valve V.13.

On ranges 1 and 2 a resistance capacity combination couples into a single tuned inductance. Tuning in all cases, however, is provided by the second section of C.71. Frequency changing is accomplished by cathode injection of the local oscillator signal provided by V.14. This is a cathode coupled oscillator, the frequency being determined by L.18 and the third section of C.71 and trimmer in conjunction with padding condenser C.64.

Damping of the R.F. circuits has been carried out where necessary to maintain bandwidth.

I.F./Output Unit (Figs. 7 and 9)

Signals from the R.F. Unit are taken from V.13 anode via a co-axial cable to the I.F. amplifiers V.6 and V.7. IFT1, 2 and 3 are the transformers associated with these amplifiers. To enable the range of gain required to be obtained the screen voltage of V.6 is also derived from the R/F gain control line, but is connected via contacts on Switch S.2 providing the zero setting facility previously mentioned. Mid-band intermediate frequency is 465 kc/s and to obtain the required bandwidth the primaries (top trimmers) and secondaries (bottom trimmers) of the I.F. Transformers are tuned to 468 kc/s and 462 kc/s respectively.

Valve V.8 (operating as a cathode follower) feeds, via a co-axial inter-chassis lead, the output of V.7 to the valve voltmeter system V.1, V.3 and V.4 (fig. 4). The latter pair form a bridge circuit with the output meter connected between the cathode loads. Provision is made to equalize the voltage at these cathodes under no signal conditions and drift due to thermal changes is minimized by duplicating the associated circuits of each valve as far as possible. Nominal matching of valves V.3 and V.4 is necessary to obtain a balanced condition within the range of control provided. The limiting diode, a section of V.2, is connected across the input to V.3 and conducts should the signal become excessive.

The output meter is calibrated directly in decibels and the figure indicated plus the amount of switched input attenuation included gives a measure of the received signal expressed as decibels above 1 microvolt. The rectifying circuit, V.1, R.1, C.3 with its load R.4 plus R.5 has been designed to accommodate high amplitude individual pulse signals as well as normal C.W. or rapidly repeating pulse signals.

Signals from V.8 are also fed via C.1 to the other section of V.2 for detection and subsequent amplification by V.5. The output of V.5 is then fed to the headphone jack on the front panel and is available for monitoring purposes.

Power Unit and Calibrator (fig. 11)

The calibrating signal is obtained by producing a voltage pulse across R.33, with an extremely sharp leading edge. This pulse contains harmonics extending over the frequency range of the set.

The gas filled tetrode V.10 is maintained in a non-conducting condition by the large negative potential applied to its grid via R.29, V.9 is a free running transitron oscillator operating at approximately 2,000 c/s. The output of V.9 fed via C.23 applies a positive pulse to the grid of V.10. This valve conducts, discharging C.24 and producing a sharp pulse across R.33.

The high anode load of V.10 drops the anode voltage to zero on discharge of the condenser and gives a rapid return to the non-conducting state.

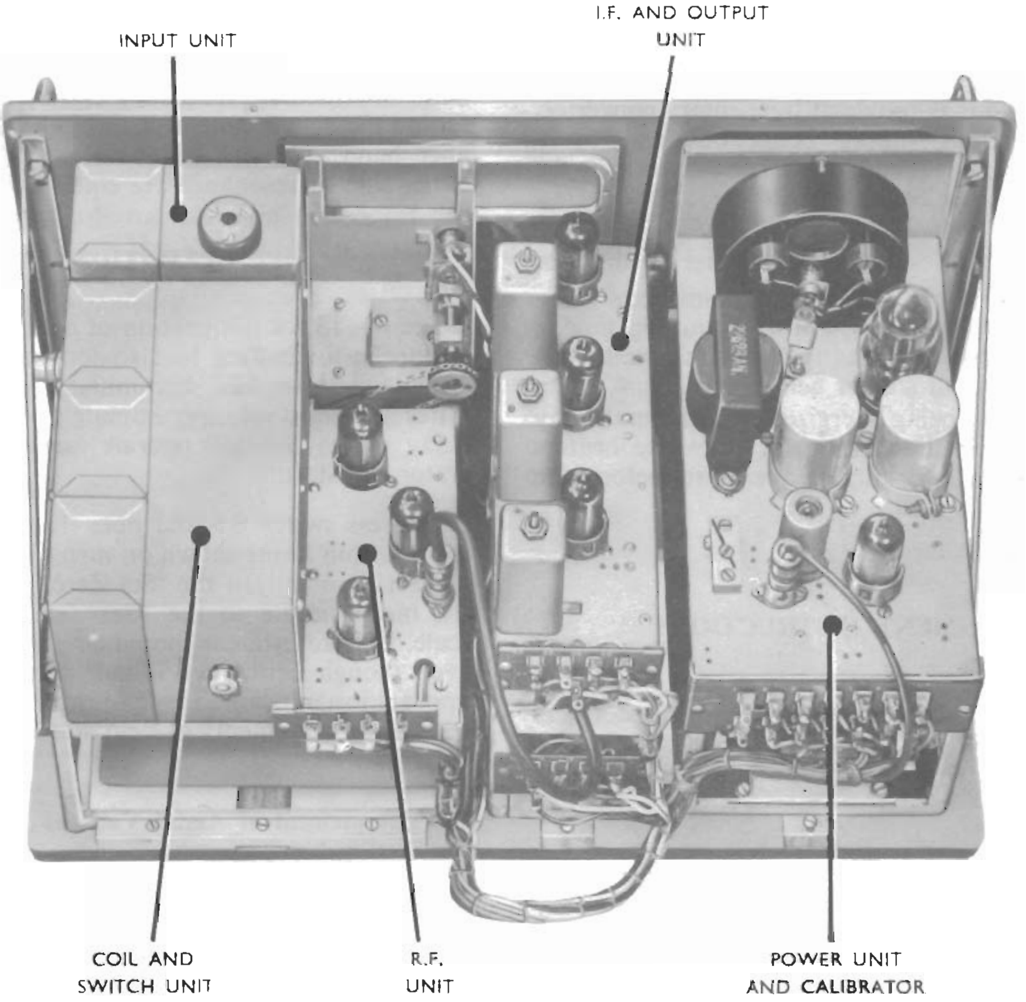

Fig. 2 Internal view of Interference Measuring Set showing arrangement of units.

The nominal amplitude of this signal, preset by adjustment of R.80 is initially set to equal an external 6 Mc/s signal of 10 decibels above 1 micro volt. After attenuation by R.35 and R.34 the calibration signal is fed by co-axial cable to the input unit and after further attenuation by R.66, R.67 and R.68 (fig. 3) it is applied via Switch S.2 to the receiver input. A small amount of capacitive correction is applied across R.67 to maintain the level at the higher frequencies.

Power required is taken from a 12 volt accumulator, the valve heater circuits being connected in a series parallel arrangement (fig. 11). H.T. of approx. 400 volts is provided by a rotary convertor, the negative bias supply being obtained by a stabilizer valve V.11 and resistance network in the negative to chassis return.

Switch S.5 enables the output meter to monitor the supply voltage as required.

The L.T. supply is fed to the rotary convertor via a starting relay and a filter network L.3, L.4, C.26, the starting relay being energized by a thermal delay switch S.4 which allows time for the valve heaters to attain normal working temperature before the H.T. supply is applied.

ALIGNMENT INSTRUCTIONS

I.F. Alignment

Align primaries (top trimmers) of transformers IFT1, IFT2, IFT3 to 468 kc/s. Align secondaries (bottom trimmers) of the transformers to 462 kc/s.

R.F. Alignment

Before carrying out this alignment it is necessary to ascertain that the scale pointer indicates the minimum frequencies on the various ranges when the condenser gang is set to maximum capacity.

With a C.W. signal injected into the input socket, align the oscillator circuits to obtain the required frequency coverage, setting the appropriate inductances and trimming capacitors to the frequency tables below.

Alignment of the signal circuits at the tracking frequencies stated can be carried out using the internal calibrator signal.

Oscillator Alignment

Range	*Inductance*	*Frequency*	*Trim. Cap.*	*Frequency*
5	L18	150 kc/s	TC11	400 kc/s
4	L19	550 kc/s	TC12	1,500 kc/s
3	L20	1.44 Mc/s	TC13	3.9 Mc/s
2	L21	3.8 Mc/s	TC14	10.8 Mc/s
1	L22	11.0 Mc/s	TC15	29.0 Mc/s

Signal Circuit Alignment

Range	*Inductance*	*Frequency*	*Trim. Cap.*	*Frequency*
5	L5 & L10/L11	162 kc/s	TC1 & TC6	310 kc/s
4	L6 & L12/L13	615 kc/s	TC2 & TC7	1,250 kc/s
3	L7 & L14/L15	1.6 Mc/s	TC3 & TC8	3.2 Mc/s
2	L8 & L16/L17	4.3 Mc/s	TC4 & TC9	8.8 Mc/s
1	L9 & L18/L19	12.5 Mc/s	TC5 & TC10	25.0 Mc/s

With the measuring set adjusted to 400 kc/s inject a C.W. signal of mid-band frequency into the low impedance input socket and adjust the I.F. rejector circuit trimmer, C70, for minimum output noting that resonance is obtainable. Peaking at mid-band intermediate frequency can be ascertained by tuning the signal generator through the I.F. acceptance band and noting that the peaks occurring on either side of resonance are equal within 1 db.

OPERATION

General

See fig. 13 for designation of controls.

Plug in the battery lead to socket on front panel and connect to 12v. accumulator, switch on S.6. After a period of approximately one minute the delay switch S.4 will operate and the rotary generator will start.

Depress switch S.5 and note that battery voltage reads within limits shown on meter. With switch S.2 to "Set Zero" adjust the "Set Zero" control to bring the meter needle to the "Set Zero" mark on the scale. This adjustment should be checked frequently even though drift after initial warming up period appears insignificant. The set is now ready for carrying out measurements of field strengths or terminal voltages.

1.—Measurement of Aerial Voltages

(a) *Open Wire Aerials*

Measurements on open wire aerials can be carried out by connecting the measuring head (item 7) to the input socket at the side of the instrument. The aerial and earth are connected to the appropriate terminals on the measuring head. Set the Voltage/Field switch to Voltage position. Set the range switch to the frequency range required and proceed to carry out tuning over the whole range. Whilst searching in this manner it will be of assistance to monitor with the headphones and the gain control should be adjusted so that inherent receiver noise can be clearly heard without being excessive. The gain of the set is dependent on the frequency range and tuning, and therefore, it is important to ensure that weak signals are not lost due to this control being badly adjusted. Reference to the calibrator signal described below enables the gain to be kept at a normal level during searching, but the presence of receiver noise is also a guide in this respect.

When tuning has been completed and it is desired to measure a particular signal, switch S.2 to "Calibrate" and adjust the gain control to bring the meter needle to the "Cal" mark on the scale, at the same time the calibrator signal modulation tone will be heard in the headphones. Allow switch S.2 to return to "Measure" and switch in sufficient attenuation to obtain a meter reading, without altering the gain control. Then the amplitude of the signal in decibels above 1 microvolt is given by the sum of the meter reading, the amount of switched attenuation +8 d b (to take account of the measuring head transformation ratio 500 to 80 ohms).

(b) *Whip Aerial.*

The aerial feeder may be connected directly to the input socket to the set and measurements carried out as above.

2.—Field Strength Measurement

Insert the extendable rod aerial in the socket on top of the set and turn the Voltage/Field strength switch to the "Field" position, then proceed as for aerial voltage measurements.

The amplitude of the signal is then given by the sum of the meter reading, the amount of switched attenuation and the correction factor appropriate to the frequency as given by the chart (curve in fig. 14).

3.—Voltage Measurement

Connect the single way co-axial cable to the input socket at the side of the instrument. Connect the three way selector switch to the end of this cable and then interconnect the selector switch and three way mains connection unit by means of the three way co-axial lead supplied. Colour markings are provided on these items to facilitate correct connections. The terminals on the mains connection unit should then be connected to the circuit on which it is desired to conduct measurements and the selector switch set to the appropriate position. Provision has been made to enable connection to be made to two or three wire systems and any terminal selected at will, whilst measurements are being made.

With the Voltage/Field switch set to the "Voltage" position tuning and calibration are carried out as for aerial measurements.

For accommodating signals from 0.1—0.3 volts the voltage range of the equipment can be extended when desired by setting the calibrator signal to 0db on the meter scale and adding 10 db to the sum of the input attenuation included and the reading on the output scale, this giving an available total of 110 db above 1 uV.

PART II

RADIO INTERFERENCE

INTRODUCTION

The term interference, as applied to radio reception, refers to any signal or disturbance which can mar the reception of a wanted signal. Generally speaking, radio interference may be classified under three main headings:

(i) Atmospheric disturbances.

(ii) Interference caused by c.w. sources such as other transmitters, receivers and industrial, scientific and medical radio-frequency equipment.

(iii) Interference caused by electrical machinery and installations.

In studying interference on board ship problems arising under (i) and (ii) are more the concern of the designer than of electrical officers and contractors. We are, therefore, mainly concerned with interference arising from operation of the ancillary equipment of the ship. In what follows it is assumed that it is with this class of interference that we are concerned, though much of the technique will also be applicable to interference arising under clause (ii).

Generation

It is well known that sudden variations in the currents flowing in one circuit can cause currents to flow in a second circuit coupled to, but not directly connected to, the first circuit. The currents in the secondary circuit will depend upon the magnitude and rate of change of the variations in the primary circuit, the impedance-frequency characteristic of the secondary circuit and on the degree of coupling between the circuits. In general, the larger and more rapid the variations in the primary circuit, the larger will be the currents and voltages induced in the secondary circuit; the broader the band of frequencies accepted by the secondary circuit, the larger will be the amplitude of the induced disturbance, and the shorter will be its duration. Obviously the tighter the coupling between the circuits the greater will be the energy transferred from one circuit to the other.

The normal operation of many electrical appliances and machines involves sudden changes in the current taken by the machine from the supply mains, e.g., thermostatically controlled devices, commutator motors such as fan motors, gyro-compass units, rotary converters, winch and capstan motors, etc., fluorescent lighting, electrical signalling circuits involving " M " type and similar transmitters fitted to compass or Asdic equipment and the ignition systems of internal combustion engines. The sudden variations of current produced by the operation of such equipment can cause currents to flow in the aerial-earth circuits of the radio receiving equipment. These latter currents can produce shock excitation of the receiver at the frequency to which it is tuned, and, depending on the magnitude of the disturbance, noise may be heard on the output of the receiver superimposed on the wanted signal. This noise constitutes the interference with which we are concerned.

Propagation

The sudden changes in the supply current to a machine are, in general, propagated along the wiring associated with or connected to the machine in two ways:

(i) as currents or voltages existing in the circuit formed by the electrical wiring to the machine;

(ii) as currents or voltages existing in the circuit formed by these wires and earth.

The former are referred to as symmetrical currents and voltages and the latter asymmetrical currents and voltages. Generally speaking, the asymmetrical components cause more interference than the symmetrical components, as the latter are generally in circuits which form only small loops and hence couple only loosely with other circuits. Since the sudden current changes in the supply-mains-machine circuit are capable of exciting a response in the circuits of a receiver which may be tuned anywhere within a wide range of frequencies, it is usual to regard these current changes as a disturbance which has its energy spread more or less uniformly, as the case may be, over a wide range of frequencies from which the receiver may abstract energy in a narrow band about its tuned frequency.

The energy associated with these radio-frequency currents and voltages may be propagated to the vicinity of the radio receiving system in three ways:

(i) by direct radiation from the machine or its associated wiring;

(ii) by conduction along the mains wiring connected to the appliance;

(iii) by conduction along wires, etc., not directly connected to the machine but closely coupled to it or its associated wiring.

The intensity of directly radiated noise fields decreases very rapidly with increase in distance from the source. Common sources of directly radiated interference are radio-frequency industrial, scientific and medical equipment and the electrical ignition systems of internal combustion engines. Electric motors and motor-driven apparatus rarely give rise to directly radiated interference and such cases as are generally experienced are due more to radiation from unscreened wiring associated with the machine than to radiation from the machine itself.

When the source of interference is connected to the supply mains the radio-frequency noise currents may be transmitted with some attenuation along the mains. After conduction for some distance along the mains these currents may enter wiring in close proximity to the aerial-earth system of the receiver and be radiated from this section of the wiring into the aerial-earth system. In cases where the receiver is badly filtered in its supply leads the currents may enter the receiver via the power-lead. This case should, however, be rare.

Rigging, lanyards, mast stays, etc., may become transporters of interference if they pass close to a source producing a strong local radiated field and are also coupled closely to the aerial system.

MEASUREMENT

General

Apart from the case of radiation direct from the machine it is clear from the foregoing that the interference caused will be more or less proportional to the currents or voltages injected into the wiring to the machine. The larger these currents and voltages, the greater will be the interference. Also the current in the wiring will vary as the voltage appearing at the terminals of the interference producing machine.

Thus a convenient measure of the ability of an equipment to cause interference will be the voltages which it injects into the mains wiring (i) between the poles of the mains—the symmetrical voltage and (ii) between the mains wiring as one pole and earth as the other—the asymmetrical voltage. It is, however, difficult to ensure an accurate measurement of the symmetrical voltage over the whole frequency band up to 30 Mc/s. For this reason it is customary to measure the voltages between each mains supply line and earth. These voltages are closely related to the symmetrical and asymmetrical voltages and thus may be used as a measure of the ability of the machine or apparatus to cause interference.

Where the machine or equipment does not derive its power from a supply mains, e.g., internal combustion engine, the only appropriate measure of its ability to cause interference will be a measurement of the field in the neighbourhood of the equipment.

Measurement of Terminal Voltages

The full test procedure for laboratory use is described in British Standard No. 727 "Characteristics and Performance of Apparatus for the Measurement of Radio Interference." For *ad hoc* tests on board ship when it is desired to know whether a machine is producing excessive noise it is convenient and permissible, provided care is taken, to omit certain details of the laboratory set-up.

A measuring head (2 fig. 1), is supplied for this purpose and permits measurements to be made on single-phase or 3-phase machines and on d.c. machines with a third lead brought out from the field winding. This network connects each line to earth via a substantially resistive radio-frequency impedance of 150 ohms. The input to the measuring set forms part of one of these impedances and is arranged to be switched to each line in turn. When more than three lines are connected to the machine, e.g., some repeater motors and transmitters, the extra line or lines should be connected to earth via a 0.1 μF capacitor and a carbon resistor of 150 ohms in series. It is essential that all lines coming from the machine under test be connected to earth via such an impedance, otherwise considerable errors in the indicated levels may result.

In assessing the terminal voltages from a machine each line should be measured in turn and the highest such voltage regarded as the measure of the ability of the machine to cause interference.

Measurement of Field Strength

When necessary, the fields around the equipment or at various places on the upper deck of the vessel may be measured directly using the small aerial supplied with the measuring set. However, the best method of checking the overall conditions on shipboard is to measure the noise voltages appearing at the base of the ship's own aerials. For this purpose a measuring head transformation unit (3 fig. 1) is supplied which transforms the set impedance from 80 ohms to 500 ohms for use on open type aerials (*e.g.*, inverted L type) in the lower frequency bands. For measurements on aerials which are resonant (generally $\frac{1}{2}$ wave dipoles) the set voltage input termination may be connected directly to the aerial feeder.

When measurements are made using the small 41″ aerial, the gain of the measuring set is adjusted as for voltage measurements, with the field/voltage switch in the field position, and the "field" obtained by adding the aerial correction factor obtainable from the curve given in fig 14.

For voltage measurement at the base of open aerials using the 2.5:1 transformer, the receiver is set up as for voltage measurement with the field/voltage switch in the "voltage" position and 8 db must be added to all readings to obtain the level at the transformer input terminals.