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SPACED AERIAL RECEPTION—
EXPERIMENTS AT TERLING

The partial elimination of fading in the reception of long-distance short wave signals by the use of spaced aerials has been mentioned in The Marconi Review, *No.* 2.

The practical application of this method in the case of Transatlantic signals on a wavelength of 21.96 *metres which was carried out as a joint investigation by the British Broadcasting Corporation and the Marconi Company is described below.*

In 1927 a series of experiments were carried out by the Marconi Company at Broomfield, near Chelmsford, in order to investigate the advantage of using a number of aerial systems for the reception of short wave signals, these aerial systems being spaced from one another at distances of from five to fifteen wavelengths. It was observed that the fading phenomena observed on one aerial differed from those observed on another aerial spaced some distance away, and that the further the separation, within the limits of the experiment, the greater the independence of the variations of the signal received on one or other of the aerial systems. It was further observed that for a given separation between two aerial systems, the independence was more marked when the line between the aerial systems lay in the direction of the transmitting station than when it was at right angles.

As T. L. Eckersley has shown (Marconi Review, No. 2 *Loc. cit.*) in a discussion on short wave fading, the advantage of adding, in a statistically independent manner, two signals together independent of phase, reduces the variability of the resultant signal by nearly one half, while the improvement in the signal-to-noise ratio is very large, being certainly greater than 30 : 1. Further, the gain in using three aerials over using two only is at least as great as the gain of two over one.

Preliminary tests carried out at Broomfield with several receivers each connected to an aerial showed very encouraging results, and it was then decided that with the co-operation of the British Broadcasting Corporation further experiments on a larger scale should be carried out on a site leased for the purpose on the estate of Lord Rayleigh at Terling. By the end of the year 1927 masts and buildings had been erected at Terling and preliminary experiments on the type of receiver best suited for the purpose had been carried out in the Works at Chelmsford. In January, 1928, the receiving apparatus was installed at Terling, and observations carried out on signals from two aerial systems separated by a distance of two miles. The signals used for the purpose of observation were short wave broadcast programmes from W-2XAD, on a wavelength of 21.96 metres.

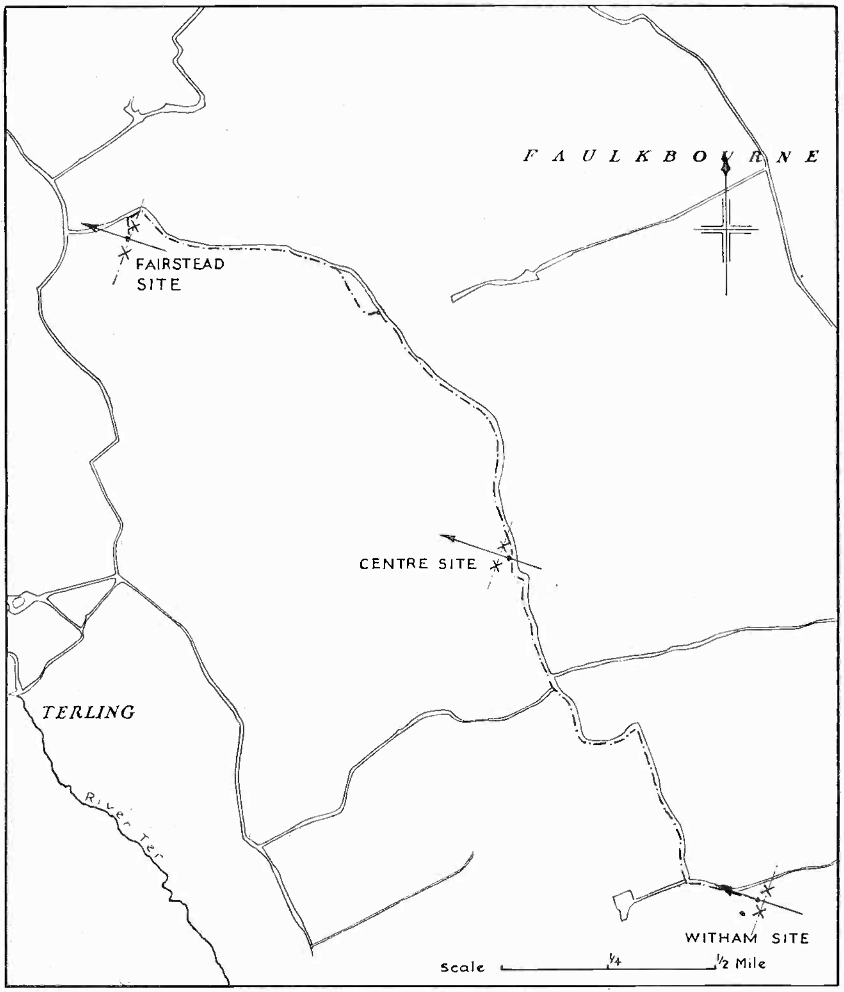


FIG. 1.

Some months later, in view of the promising results obtained in the initial tests at Terling, a third aerial site was added, midway between the already existing systems, and the receiving equipment rebuilt and improved.

It is now proposed to describe the aerial systems and the receiving equipment employed at the Terling receiving station.

Aerial Systems.

The arrangement of the aerial sites in plan is shown on the Ordnance Survey map on Fig. 1. It will be seen that the three aerial systems are separated from one another by approximately one mile intervals in the direction of New York, and by half mile distances at right angles to New York. It would have been preferable possibly to arrange these aerial systems on one great circle to New York, but the position of the site available would not permit of this.

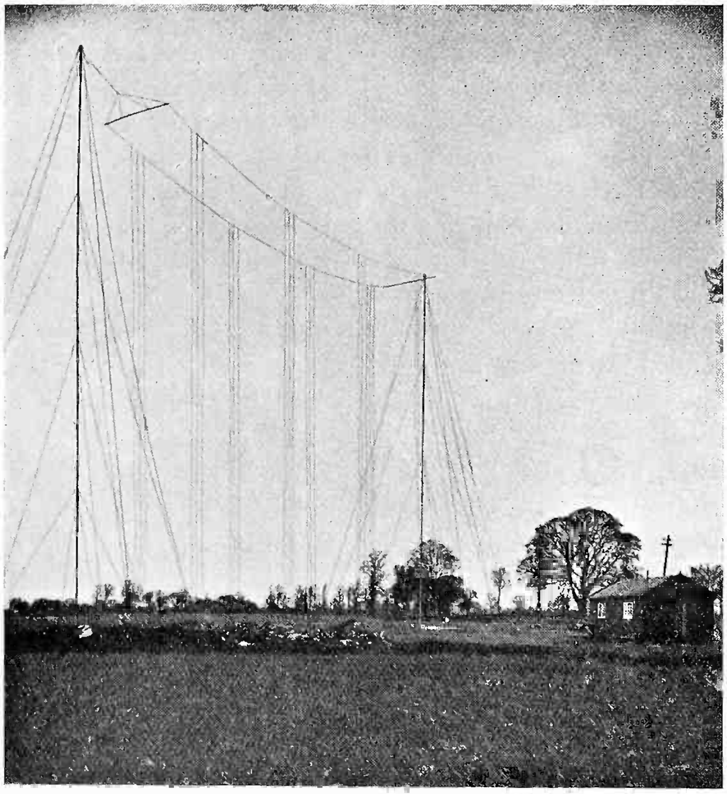


FIG. 2.

The aerial systems in use at Terling consist of small "beam aerials" comprising four Franklin aerial units each of the equivalent height of three half-wavelengths (see Fig. 2). These systems are provided with reflectors, and are directed on a great circle to New York, the true bearing being 289° E. of N. The feeders from the aerial coupling boxes are of the Franklin type, and terminate in a small hut. While the polar diagram of such a small system is not nearly so good as that obtained with the large receiving aerials used at the beam receiving stations, yet the signal strength is noticeably improved by the use of four aerial units, and the signal-to-noise ratio very much improved by the use of reflectors.

The aerial units used at first were of the Franklin type using " phasing coils " ; but these were later replaced by those of the " uniform type," which proved superior. The aerials were designed for maximum response at a wavelength of 22 metres.

Receiving Equipment.

The receiving equipment employed consists of three double detection receivers, one for each aerial system. The apparatus is mounted on racks and occupies five bays, 75 in. in height by 21½ in. A view of the apparatus in the centre hut is shown in Fig. 3.

The intermediate frequency amplifier of each receiver is divided into two parts, half being situated at the aerial site itself, and the remainder in the centre hut. In this way it is possible to avoid the difficulties which are encountered when many stages of radio frequency amplification are connected in cascade. The distant aerial sites are connected to the centre hut by means of two pairs of overhead transmission lines, one pair being used for applying the output from the beat oscillator to the first detector, and the remaining pair to carry the intermediate frequency signal current to the centre hut. The latter pair is also used for switching on the filaments of the receiving equipment at the aerial site, and provides a telephone channel between the centre hut and the outlying sites.

The high frequency amplifier and first detector unit, together with the first part of the intermediate frequency amplifier, with associated relays, etc., are mounted in a small hut on a rack 30 in. high, and this part of the receiver is left unattended, except when it is necessary to change wavelength settings. The actual operation of searching is carried out from the centre hut, by varying the frequency of the beat oscillator. The operation of setting the high frequency amplifier and first detector on a fresh frequency is easily carried out by passing the signal after the second detector back along the intermediate frequency pair, and listening on a head-set at the actual site.

The intermediate frequency employed is of the order of 1,200 kc., and the whole of the intermediate frequency amplifier comprises in all four screened grid valve transformer coupled stages, the last stage being connected in push-pull in order to avoid overloading. The total measured gain in this amplifier is 110 db., and the mean peak signal voltage produced on the grids of the second detectors is of the order of 20 volts.

The high frequency beat oscillators are three in number, and means are provided so that any oscillator can be connected immediately to any or all receivers. It is possible thus to be able to receive on one frequency only on all receivers simultaneously, or to receive a programme which may be transmitted in two or three frequencies simultaneously.

The method of combining the signals after passing through the second detector is to connect the output terminals of the transformers in the plate circuits of the second detectors of the three receivers in parallel. This method proved the simplest and most satisfactory in practice. The quality of the programme and the level may be monitored at any point in the system by means of jacks. The signals then pass through a one-way repeater to the line.

The use of sharply tuned intermediate frequency amplifiers results in a very bad frequency characteristic, due to "side band cut-off." To improve the frequency characteristic of the apparatus therefore an equaliser is employed, which gives a substantially flat characteristic overall frequency up to 5,000 cycles. This is quite sufficient for good quality relaying purposes, and in some cases it is necessary to reduce the band to some 3,500 cycles to cut out noise and interference from some station working close to the received frequency. This is carried out by the use of a low pass filter.

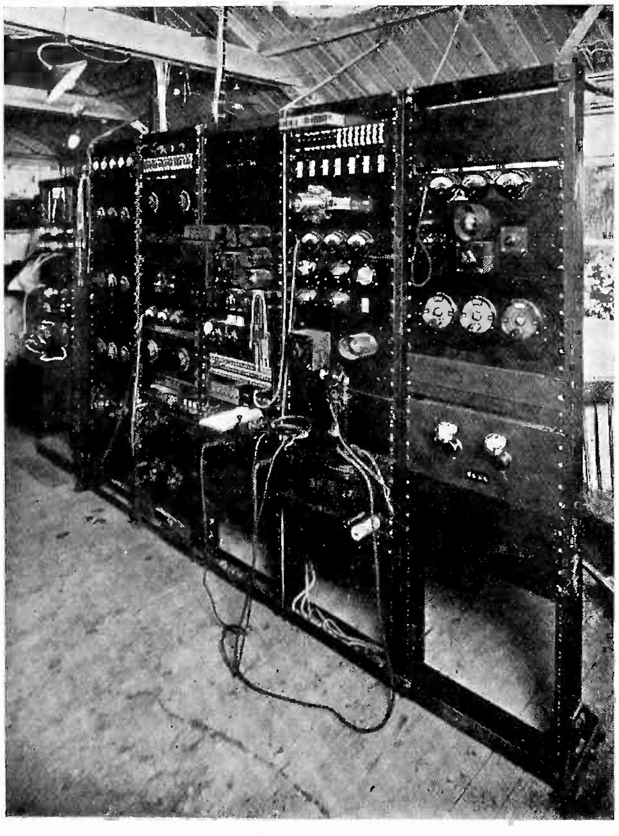


FIG. 3.

The receiver is controlled from a small control table mounted on the racks, and by means of a jack field the output from any receiver can be plugged through to the London Station control room when required. The general lay-out of the apparatus is shown on Fig. 3.

Experiments carried out during 1928-1930.

Observations were carried out during the above period with a view to judging whether the quality of the signals broadcast from the short wave stations of the General Electric Company at Schenectady, N.Y., was good enough for rebroadcast purposes. A two-way radio circuit was set up between Schenectady and Terling in order to carry out tests on intelligibility and to compare observations. This circuit was set up twice a week over a period of some eighteen months, and definitely showed that the spaced aerial system had distinct advantages over reception from one aerial only, as the intelligibility when signals were fading badly was such that it was impossible to maintain commercial speech when using one aerial only, while with the use of all three it was possible to carry on conversations with good commercial intelligibility. The results obtained are typified in the curve of Fig. 4.

The transmitter at 5SW, Chelmsford, was used for this speech channel, and the signals from England were picked up at the receiving laboratories of the General Electric Company at Sacandaga Road, South Schenectady.

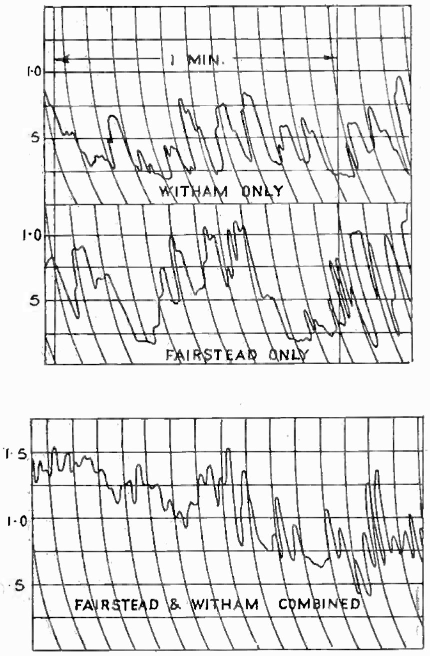


Fig. 4.

With the apparatus which has been described it was found possible to rebroadcast certain interesting events from the United States. The first relay carried out was the landing of the airship Graf Zeppelin on its first voyage to New York, which was regarded by the Press as a great success. Other relays carried out from Terling include the arrival and speech of Mr. Ramsay MacDonald on his visit to New York, the second arrival of the Graf Zeppelin at New York, and a special musical programme on Christmas Day 1929.

Experiments were also carried out on reception of telegraph signals from New York with a view to investigating whether the spaced aerial system could give an improved speed of working when signals were fading badly. Certain modifications were made in the receiving equipment in order to adapt it as far as possible for the reception of telegraph signals, and the high speed signals received relayed via a telegraph line from Terling to Radio House. It may be of interest to note that on one occasion when the lines between Somerton Receiving Station and Radio House were down, the short wave traffic between New York and Radio House was satisfactorily relayed for three hours.

In conclusion it may be stated that the spaced aerial method of short wave reception has proved of considerable utility for the purpose of providing rebroadcast programmes. The equipment at Terling is now in process of being transferred to the receiving station of the British Broadcasting Corporation at Tatsfield in Kent, where it will be installed for relaying purposes.

W. Proctor Wilson.

MARCONI AERODROME TRANSMITTER
TYPE T.A.1

The type T.A.1 Telegraph-Telephone transmitter has been designed primarily as a ground station of moderate power for use at aerodromes in communicating between aerodromes, and from aerodromes to aircraft.

Four of these transmitters have been installed in the new London Terminal Air port at Croydon, and two of these have been recently modified to meet certain requirements.

In the design of the transmitter, special attention has been paid to the question of ease of control and accessibility, and to this end the equipment is divided up into a number of units, and all controls are arranged within easy reach of the operator.

General Description.

THE T.A.1 transmitter itself, together with the aerial and closed circuit components, is shown in the photograph. It consists of an extremely compact transmitter capable of giving a service of C.W., I.C.W. and telephony over a wave range of 800-2,000 metres, and an independent drive system of wavelength control.

The component parts are mounted in an enclosed angle iron framework fitted with metal protecting screens. The controls and instruments are mounted on the front of the transmitter unit.

The range of the transmitter may be taken as of the order of 700 miles in the case of telegraphy, and 400 miles in the case of telephony when transmitting on a wavelength of 1,500 metres.

The installation is given a nominal rating of 4 kilowatts total input.

The complete equipment includes :—

(1) The transmitter unit, comprising :—
  (A) Rectifying unit.
  (B) Independent drive.
  (C) Magnifier circuit.
  (D) Modulating system.

(2) The aerial circuit unit.

(3) The closed circuit unit.

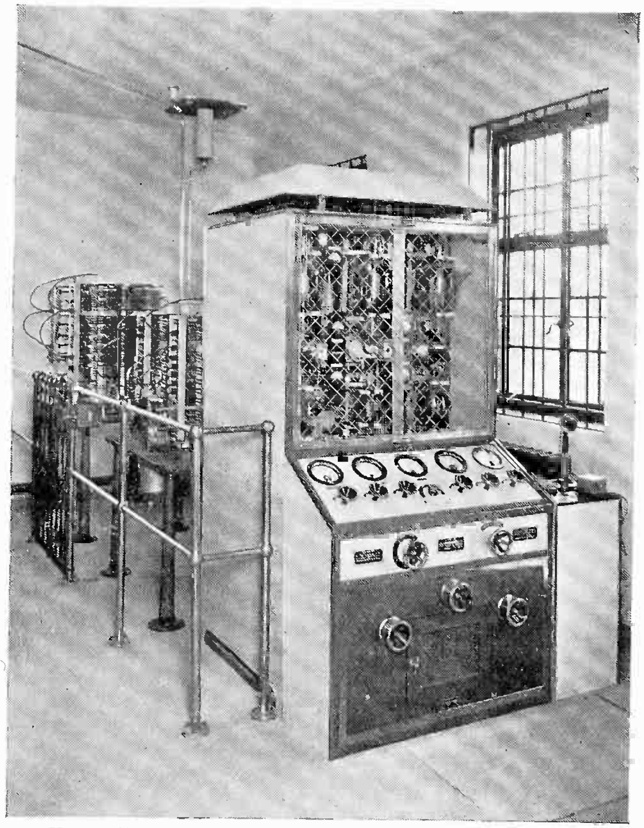
The valves used in the various units are as follows :—

Two Rectifiers	M.R.6.
Independent drive	M.T.4.
Magnifier	M.T.2.
Sub-Modulator	M.T.4B.
Two Modulators	M.T.7B.

As will be seen in what follows, the two modulating valves act as absorbers during C.W. and I.C.W. transmission.

The Rectifier Unit.

Full wave rectification is used, and the alternating current power supply is controlled by means of an auto-transformer connected between the A.C. mains and the primary of the power transformer. A smoothing choke and two condensers are placed at the bottom of the unit.



Type T.A.1 Transmitter installed at Croydon.

The high tension voltmeter, together with its resistance, is placed in circuit across a smoothing condenser to earth, and serves to discharge the smoothing system automatically when the high tension input is removed.

Two M.R.6 valves are used in the rectifier.

Independent Drive Circuit.

This unit is self-contained in a screened box which slides in the front of the set and under the control panel. Tuning is carried out by means of a variable condenser and two tapped inductances inside the box. The reaction circuit is tuned by a plug-in variable condenser, and the reaction and coupling coils are controlled by handles brought to the front. Resistance is placed in series with the anode of the M.T.4 valve to reduce the High Tension.

Magnifier Circuit and Closed Circuit Unit.

The magnifier valve type M.T.2 is mounted between the modulator/absorber valves in the top rack, and the connections are taken from the valve through insulators at the back of the set to the H.F. table, which carries the main closed circuit inductance, consisting of two inductances in series, one carrying a variometer, the other the anti-reaction coil, a variable and two fixed condensers for tuning the anti-reaction circuit. A variable condenser is used for tuning the main closed circuit, and provision is made by means of a link for inserting an extra fixed condenser if required. An H.F. ammeter is mounted on the front of the H.F. table.

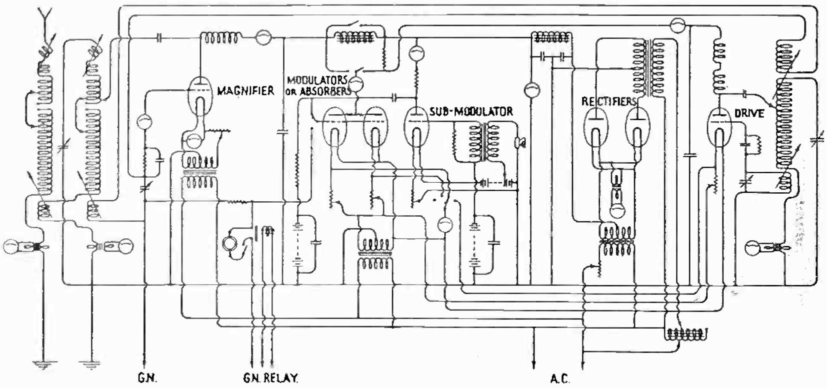


FIG. 1.

Aerial Tuning Inductance Unit.

The two aerial tuning inductances are wound with stranded wire on porcelain insulators. They are tapped at a number of points for coarse adjustment, and one is provided with a variometer for fine adjustments. The other is fitted at the lower end with a coupling coil from which the closed circuit connections are taken.

Signalling Circuits.

(A) Telephony Modulation.

The speech variations are impressed by a microphone on to the grid of the sub-modulating valve, an M.T.4.B, either locally on the control table of the set, or through an amplifier and telephone cable. The anode of this valve is resistance-capacity coupled to the grids of the two modulating valves (two M.T.7 B's), which are prevented from self-oscillation by resistances in their anode circuits. Modulation of the carrier wave is performed by speech choke control to the anode of the magnifier valve.

Continuous Wave and Tonic Train Signalling.

When transmitting on Continuous Wave or Tonic Train the speech choke is shorted, the sub-modulator is not used, and the two modulating valves act as absorbers.

The principles involved in the method of keying on the absorber system are well known, but may be briefly recapitulated here.

During a space period, a positive potential is applied to the grid of the absorber valves, the anode-filament circuits of which are connected across the oscillating circuit of the magnifier valve. Due to this positive potential the impedance offered by the absorber valves becomes low, and the magnifier ceases to oscillate. At the same time (*i.e.*, when the manipulating key is raised) a negative potential is applied to the grid of the magnifier valve, and the high tension supply to the drive is cut off. The oscillations of the magnifier circuit, therefore, cease abruptly.

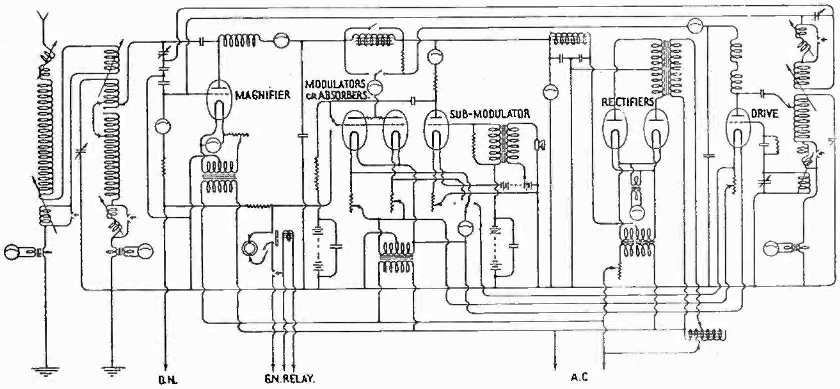


FIG. 2.

During a mark period, a negative potential is applied to the grids of the absorber valves, thereby rendering them non-conductive, and the magnifier is free to oscillate.

For tonic train a motor driven interrupter disc is inserted in the grid circuit of the absorber valves.

The manipulating key operates a creed relay, the contacts of which are in parallel with the tonic train interrupter. The relays and motor operating the interrupter are operated from a 30 volt D.C. supply.

The control panel is placed in a sloping position at the front of the set, and carries all the control instruments.

A diagram of connections of the type T.A.1 transmitter is given in Fig. 1.

Modifications to Croydon T.A.1 Transmitters.

Certain alterations have been made to some of the T.A.1 transmitters installed at the London Terminal Air Port, and chiefly concern wave change switching and remote control apparatus.

Wave Change Switching.

Three relays, controlled by a master relay, effect the wave changing of the drive, magnifier closed circuit, and aerial circuits, from one of two selected waves about 30 metres above and below the spot wave of 900 metres.

For this purpose additional variometers have been inserted in the drive, drive coupling circuit, magnifier closed circuit and aerial circuits, the anti-reaction coil in the closed circuit has been removed, neutralising being carried out by a neutrodyne condenser.

Remote Control Apparatus.

Relays are provided :—

(1) For switching over from I.C.W. to C.W. on telegraphy.
(2) To control filaments and power supply.

These modifications are shown in Fig. 2.

In addition to the above modifications, delay-action switches have been fitted to all the four transmitters installed at Croydon. These devices cause the valves first to light up with a resistance in series with the filaments, then to attain their working brightness on the automatic withdrawal of this resistance, and finally to receive the correct power supply, each separate action occurring a few seconds later than the preceding one. As the function of these switches is entirely automatic and constant, the life of the valves is lengthened, as is also the starting up of the transmitter simplified.

THE MARCONI LOW VOLTAGE CATHODE RAY EQUIPMENT

AND ITS APPLICATION TO THE MEASUREMENT AND EXAMINATION OF THE MODULATION AND LINEARITY OF BROADCAST TRANSMITTERS

The apparatus required for examining and measuring the modulation of Broadcast Transmitters, for detecting distortion and for localising faults producing distortion is described with the exception of a Phase Corrector which will be dealt with in a later article to be published in this journal. The methods adopted and the circuit arrangements used for the above investigations are also explained.

THE Oscillograph or Cathode Ray Tube used is the low voltage oscillograph manufactured by Standard Telephones and Cables, Ltd. The tube will not be fully described here since its characteristics and construction are fairly well known. For the benefit of those who are unfamiliar with the tube it will probably suffice to say that an electron beam is produced with an anode potential of 300 volts by the use of a heated cathode. The beam is made to pass through two pairs of deflecting plates known as the "Py" and the "Px" pairs, situated at right angles to one another, for the purpose of deflecting the beam as described later. The beam then strikes a fluorescent screen on the inside of the tube, on which the deflections are depicted. Focussing of the spot is carried out by a fine adjustment of the filament current when the beam is not deflected. The filament current is of the order of one ampere and the anode current is approximately ½ milliampere. A photograph of the Cathode Ray Tube and Box is shown in Fig. 1, while Fig. 2 shows the circuit used for the oscillograph box.

The Cathode Ray Tube Unit.

The Cathode Ray Tube Unit is a metal-lined wooden box containing the Oscillograph Tube socket mounted on a turntable; the metal screen being connected to an earth terminal. The box also contains apparatus for measuring the deflection of the spot produced by the beam impinging on the fluorescent screen and means for focussing the spot, together with a resistance to protect the tube from damage due to the formation of an arc. A two position key is fitted which lights the filament when operated in a downwards direction and which lights the filament and applies the high tension to the anode when operated in an upward direction. This key should not be used in the upward position unless observations are being taken, as the life of the tube is limited. A push button is fitted in front of the box for operating the H.T. supply and wherever possible this key should be used with the two position key operated to the downward position.

There are also two press keys fitted for short-circuiting the two pairs of plates. These keys must not be used if the application of a load to the apparatus connected to the plates is likely to cause damage.

The inside of the box and its internal fittings are painted to have a dull black surface.

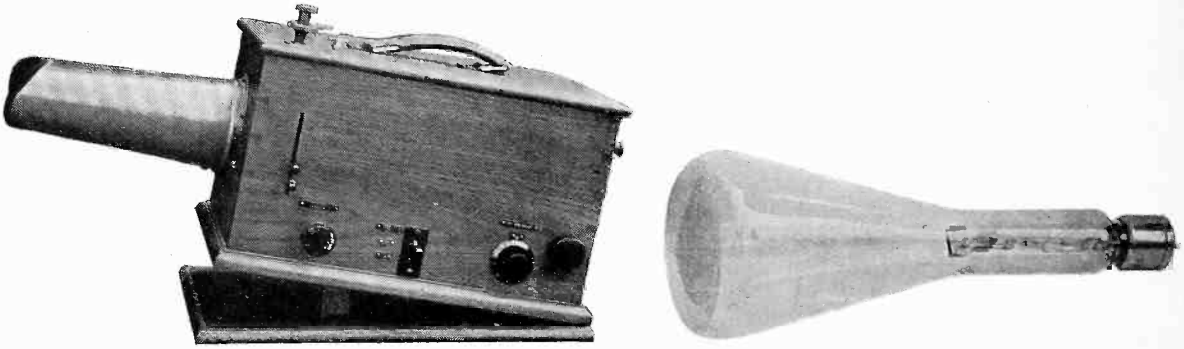


FIG. 1.

The box is light-proof and is fitted with an eye-piece, which is removable. The eye-piece is fixed by means of screws on its periphery and may be placed inside the box for transport purposes. The arms of the measuring device which are described later may also be removed and placed inside the box for transport.

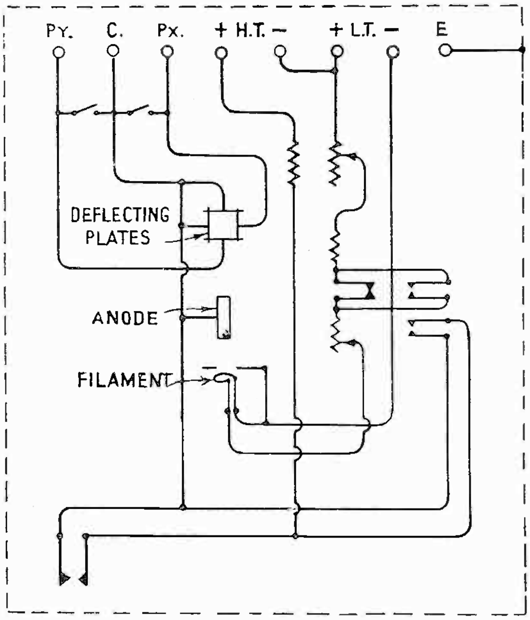


FIG. 2.

An adjustment for the height of the eyepiece is provided by means of a hinged base and a wooden block which may be inserted at any one of a number of fixed points. The block can be carried inside the box when not in use.

Cathode Ray Tube Measuring Device.

The device consists of two horizontal arms with their adjacent edges parallel and mounted in front of the screen of the tube in such a manner that they can be moved vertically (see Fig. 3). The top arm may be moved alone or the two arms may be moved together by rotating the upper or lower of the two concentric thumbscrews respectively. The arms are removable in order to facilitate transport and to enable the tube to be taken out of the box.

The movement of the lower arm moves a scale along a fixed pointer mounted outside the Cathode Ray Tube Box, so that the position of the figure to be measured is indicated on the scale, which is engraved in centimetres. The upper arm carries a pointer which moves in a slot in the moving scale and indicates the distance apart of the two arms, thus enabling the height, or change of height of any figure to be measured.

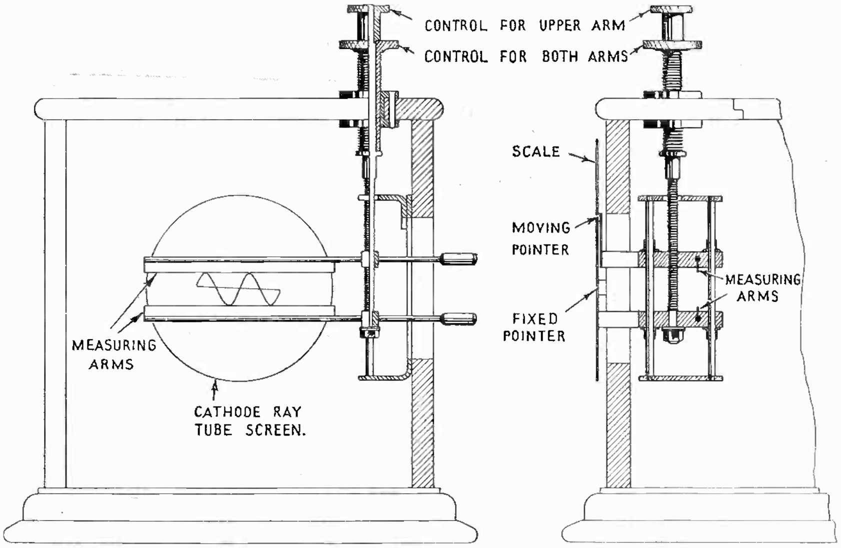


FIG. 3.

A turntable operated by a handle is fitted at the side of the box on which the Cathode Ray Tube socket is mounted, thus making the tube rotatable about an angle of approximately thirty degrees in either direction from the vertical. By rotating the tube the figure depicted on the screen may be brought into a vertical position.

In order to ascertain whether a figure is vertical, a potential should be applied to the " Py " plates, the " Px " plates being short-circuited. This will produce a line which should be vertical, and the turntable should, if necessary, be rotated until such is the case. If, due to the application of another potential to the " Px " plates, the figure then inclines to one side, such action is due to a difference in phase between the two potentials and the tube should not be rotated. The amplitude to be measured will then be as shown in Fig. 4.

The scales are, as stated before, engraved in centimetres, so that the distances measured by the arms may be read off directly from the front of the box.

If accurate quantitative measurements are to be made it is perhaps advisable to calibrate the tube with D.C. potentials. This calibration is, however, not required, for ordinary work as the tube is generally used for the comparison of two quantities for depicting the shapes of waves, or for the measurement of percentage modulation where the results depend upon the ratio of two measurements.

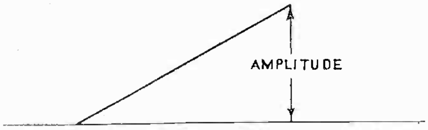


FIG. 4.

The Cathode Ray Box also contains a coarse and a fine filament resistance, together with an anode protective resistance and two keys for short-circuiting the two pairs of plates.

Auxiliary Apparatus.

The following apparatus is required for the examination and measurement of modulation and linearity :—

1	Variable Frequency Oscillator	
1	Time Base (for examination only)	
1	Rectifier Unit	For measurement only
1	Phase Corrector	
1	Pair Radio Frequency Chokes	
1	300 volts battery of dry cells (Ever-Ready Radio or similar battery)	
2	6 volts 20 A.H. Accumulators	
	Lead-covered cable for connections	

Variable Frequency Oscillator.

Any source of variable frequency may be used but the Marconi Variable Tone Generator is recommended. This instrument provides a constant output over a frequency range of 20 to 10,000 cycles and was described in the March issue of this journal.

Time Base.

The Time Base (see Fig. 5) consists of a circuit as shown in Fig. 6c of which the chief features are a neon tube, a variable resistance in the form of a diode, and a variable capacity. The apparatus works on the well-known principal by which a condenser charging at a controlled frequency is allowed to discharge through a neon tube, as in Fig. 6a. The frequency is controlled by an adjustment of the capacity of the condenser, and by altering the filament resistance which has the effect of altering the filament impedance of the diode, and consequently controls the rate of charge of the condenser. When the charge on the condenser reaches the striking potential of the neon tube, it discharges through the tube until the condenser charge reaches the point at which the lamp goes out, whereupon the cycle repeats itself. An ideal time base curve is shown in Fig. 6b.

The potential developed across the neon tube is then fed to the " Px " pair of plates, and, as the discharge time is almost instantaneous compared with the time taken to charge the condenser, the cathode ray beam slowly traverses the screen from left to right as viewed through the eye-piece, and returns to its normal position very rapidly, thus providing an almost ideal time deflection. The deflection of the spot by the time base is very nearly linear with respect to time.

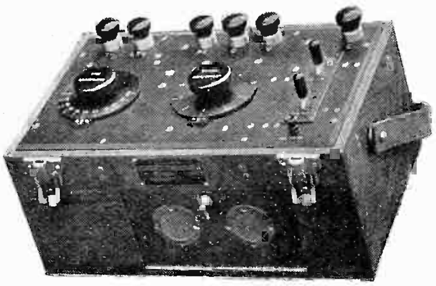


FIG. 5.

The time base circuit is arranged to accept a very small amount of energy from the circuit under investigation and this energy is sufficient to keep the time base pulses in synchronism with the frequency being examined.

It is obvious that if a periodically varying EMF be applied to the " Py " plates, and the time base be used to draw out the figure along a horizontal axis, the actual form of the wave may be seen. It should, however, be appreciated that, since the amplitude of the wave and the length of the time deflection are separately controlled, the wave will appear peaked or levelled, according to the ratios adopted, exactly as a pure sine wave, if drawn on a sheet of graph paper, will be levelled or raised as the " x " and " y " scales are altered.

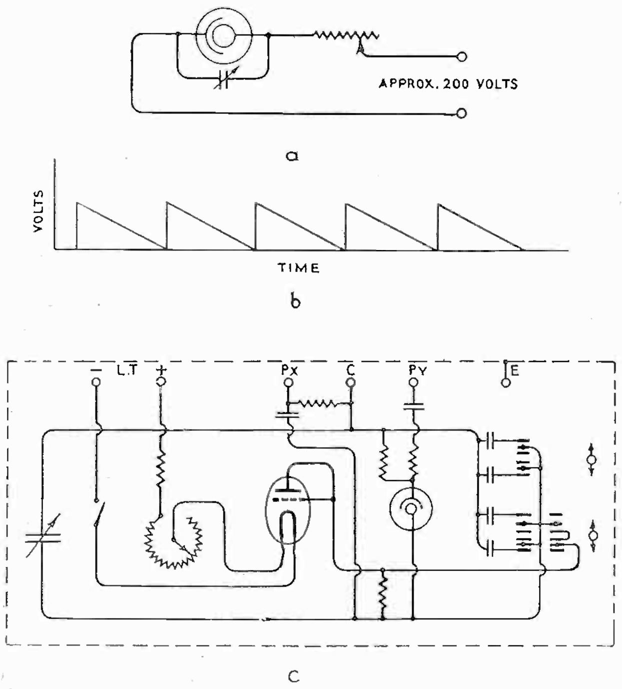


FIG. 6.

With the foregoing proviso, any wave shape may actually be inspected with the aid of the Cathode Ray Oscillograph and Time Base.

The Diode used is a special valve designed to obtain very smooth impedance control.

Rectifier Unit.

A photograph of the Rectifier Unit appears in Fig. 7, and the circuit is shown in Fig. 8. The Rectifier Unit is screened and consists of a Pick-up Coil in a protective handle to avoid danger to the operator when placing the coil near a high-powered transmitter. The coil is connected to the Rectifier Unit by means of a length of flex, and is tuned to the wavelength of the transmitter by the condensers incorporated in the Unit. The energy received is rectified by the diode valve and the output is taken from the ends of the 10,000 ohm resistance through a lead-covered cable to the Radio Frequency Chokes. Since the Rectifier output is direct current the use of lead-covered cable is admissible. The cable sheath and the screen of the rectifier should be earthed to prevent direct pick-up.

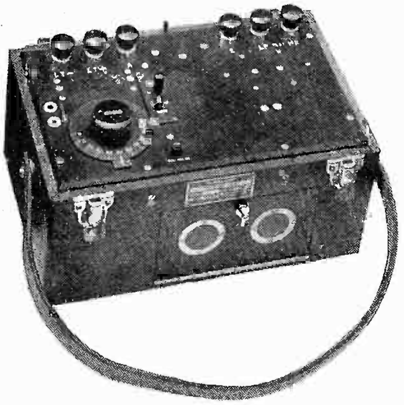


FIG. 7.

A Radio Frequency Choke and bye-pass condenser are incorporated in the Rectifier Unit, and the choke and pick-up coil should be changed for each range of wave lengths.

Coils and chokes are normally supplied for the following ranges :—

PICK-UP COILS.	R.F. CHOKES.
200– 500 metres	200– 300 metres
500–1,000 ,,	300– 500 ,,
1,000–2,000 ,,	500–1,200 ,,
	1,200–3,000 ,,

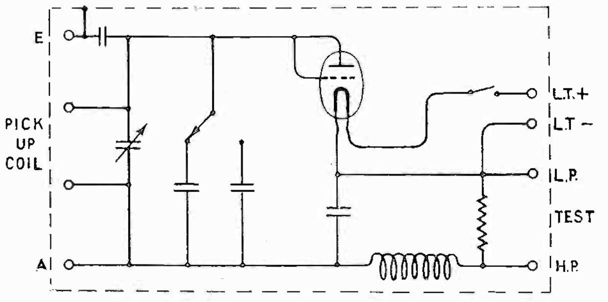


FIG. 8.

The diode used in this unit is a DEP 610 with the plate and grid connected together. The output of the rectifier is substantially constant over the audio frequency range of from 0 to 10,000 cycles when the percentage modulation of the transmitter is kept constant. This ensures accuracy in the measured results, and the rectification provided is practically linear since the diode impedance represents approximately only one fifteenth of the total impedance of the rectifying circuit.

The Rectifier Unit is arranged so that, if desired, the pick-up coil may be plugged directly into the unit and an aerial may be used to pick up energy. This method will, of course, only provide sufficient output to operate the Cathode Ray Oscillograph at very small distances from the transmitter, and the wavelength range of the instrument will be changed due to the absence of the flexible lead to the pick-up handle.

The Rectifier Unit includes a box for carrying the handle and for the coils and radio-frequency chokes when not in use. See Fig. 9.

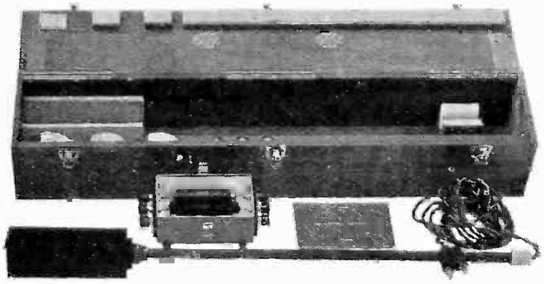


FIG. 9.

Radio Frequency Choke Box.

A small metal box, containing two radio frequency chokes and a small bye-pass condenser are included for use with the Rectifier Unit. Spare chokes for use on different wavelengths are also carried in the box in which the Pick-up Handle and Tuning Coils are transported. See Fig. 9.

This small box is known as the Radio Frequency Choke Box and is intended to be inserted at the end of the lead-covered cable from the Rectifier Unit and as close as possible to the Cathode Ray Tube Unit, in order to choke back any radio frequency energy which may have been picked up in the leads.

The box should have its earth terminal connected to earth.

Phase Corrector.

The Phase Corrector, which will be described in a future article, is used for adjusting the relative phases of two potentials applied to the tube by advancing or retarding the phase of one of them ; in this case the audio frequency is the potential selected for phase-correcting operations. Such an instrument is necessary in cases where it is desired to witness the effect of a change of phase, or to change a figure from an ellipse to a straight line for purposes of clarification. For instance, a distorted ellipse such as an hysteresis curve is easier to interpret if the figure be reduced to a BH curve, i.e., a line, in cases where the shape of the curve and not the amount of energy expended is being investigated.

The above remarks apply equally to the detection of distortion in amplifiers or radio transmitters.

Method of Examining the Modulated Output Wave of a Transmitter.

The Cathode Ray Tube Unit, and Time Base should be connected as shown in Fig. 10, separate wires being used to join the Rectifier Unit to the Cathode Ray Tube

Unit as in this case the former is being used for tuning purposes only, and the output is, therefore, radio frequency.

When the Pick-up Handle, fitted with the appropriate coil is plugged into the Rectifier Unit, and the handle is placed near the transmitter so as to pick up energy, the unit may be tuned, the " Px " plates being short-circuited and the Rectifier Unit being switched off.

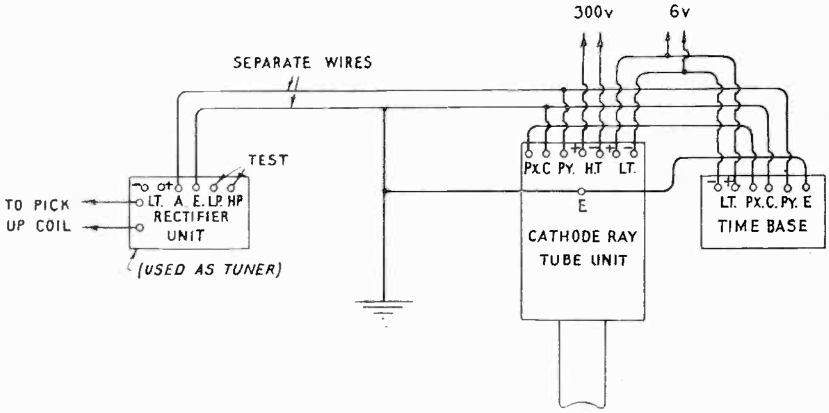


FIG. 10.

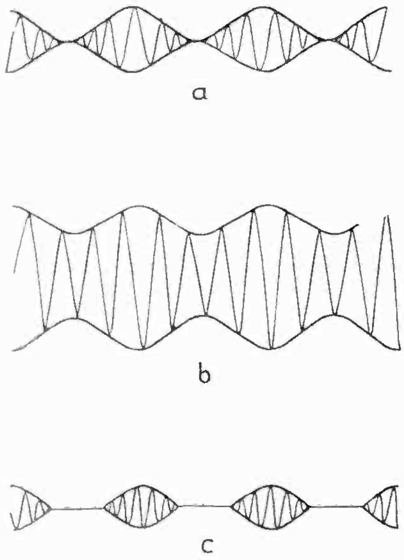


FIG. 11.

Correct tuning is indicated when the spot, which should previously have been focussed, develops into a line and the line reaches its maximum length. The maximum length of the line should always be adjusted by an alteration of the coupling of the Pick-up Coil with the transmitter, and should on no account be corrected by detuning, as the latter method will bring about inaccuracies due to cutting off the outside edges of the side-bands.

When the Rectifier Unit has been tuned, the Time Base should be switched " on," the short-circuit removed from " Px " and the frequency of the Time Base adjusted until it is, preferably, half the frequency of the modulating oscillator. The correct setting of the Time Base is immediately apparent because the modulated wave form will appear as shown in Fig. 11. If the Time Base frequency is half that of the modulating oscillator, two audio frequency envelopes will be seen, while with a Time Base frequency of one-third that of the oscillator three complete envelopes will appear.

Measurement of Percentage Modulation.

The Rectifier Unit, Radio Frequency Choke Box, Cathode Ray Tube Unit and the Phase Corrector should be connected as shown in Fig. 12, lead-covered cable being used to join the first two instruments. A separate battery must be used for the Rectifier Unit.

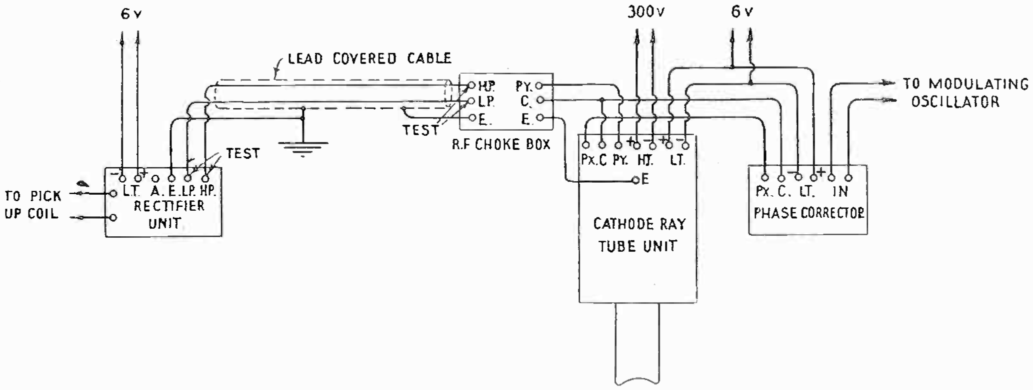


FIG. 12.

The Pick-up Coil should be located so as to pick up energy from the transmitter which should be working in an unmodulated condition, then, with the " Px " plates short-circuited and the spot focussed, the Rectifier Unit should be tuned until the spot reaches the maximum height. If the height attained is not suitable it may be adjusted by an alteration of the coupling between the pick-up coil and the transmitter. As before, de-tuning will cause errors due to filtering out part of the side-bands.

When the tuning is correctly adjusted the tube should be rotated to ensure that the line produced will be vertical. In order to do this, the transmitter should be fully modulated at any convenient frequency, which will cause the spot to develop into a line. The tube should then be turned until the line is perpendicular to the parallel edges of the measuring arms.

The modulation should next be removed and measurement may then be commenced.

The distance through which the spot has moved is proportional to the peak value of the carrier wave and should be measured as follows :—

Short-circuit the " Py " plates, thus bringing the spot to the original position and set the lower measuring arm to this point so that the edge of the arm lies along the centre of the spot. Next, remove the short-circuit from " Py " and set the upper arm to the centre of the new position of the spot, care being taken not to move the lower arm. The distance through which the spot has moved may now be read from the amplitude scale on the front of the box. A note should be made of the reading obtained, which should be designated " A."

If desired, the spot, when in position " A " may be brought to the centre of the tube by means of a biassing battery connected in series with the lead from the Radio Frequency Choke Box to the Cathode Ray Tube Unit. This battery should be of the order of 10 volts, and must be connected in the proper sense.

Now modulate the transmitter and the spot will become a line. The upper arm should now be set to the upper end of the line, and the distance between that point and the original central position of the spot should be read from the scale and called " B." This distance represents the peak value of the crest of the modulated envelope. The same procedure is adopted with the lower end of the line, the result, which represents the peak value of the root of the wave, being called " C."

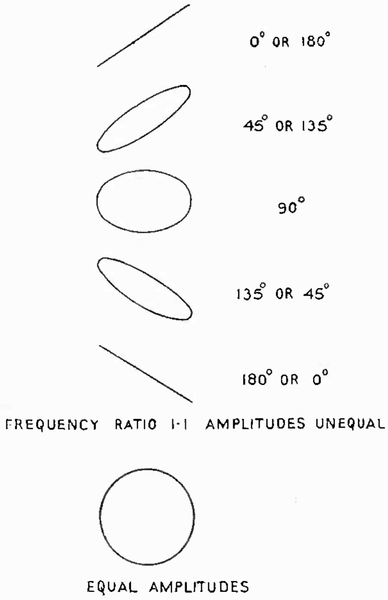


FIG. 13.

The percentage modulation equals

$$\frac{100\ (B-A)}{A} \quad \text{or} \quad \frac{100\ (A-C)}{A}$$

Detection of Lack of Linearity.

If the transmitter is linear (A–C) will be equal to (B–A). It is, however, not easy to detect the existence of small amounts of distortion by this method.

A more satisfactory method is to apply the modulating frequency to the tube via the Phase Corrector. The " Px " plates should now have the short-circuit removed and the Phase Corrector should be switched " on," when an ellipse will appear on the screen.

By rotating the phasing device, the ellipse will become a line which will be straight if the transmitter is linear and will bend over as soon as the transmitter departs from linearity. (For examples of phase relationships see Fig. 13.)

It is thus possible to increase the modulation until the line is just about to bend over, and then to measure the percentage modulation. The result obtained is the maximum percentage modulation obtainable without distortion, at the particular frequency at which the measurement was made.

Should distortion occur before the expected maximum modulation is reached, the transmitter may be tested, step by step, until the fault is located. The wrong condition existing may then be corrected, and the effect may be noted on the tube. Lack of linearity may be due to bad wave-form of the modulating oscillator, and this may be examined as described below.

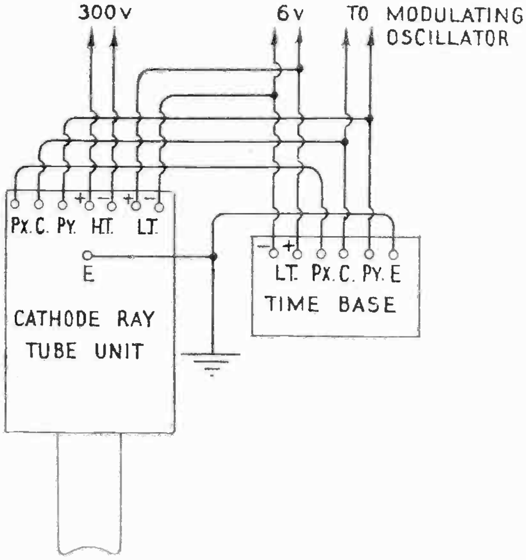


Fig. 14.

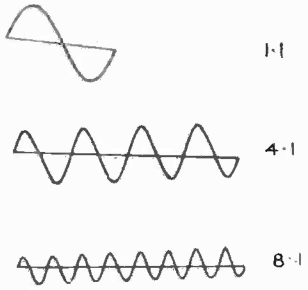


Fig. 15.

Examination of Wave-Form.

Connect the Cathode Ray Tube Unit, the Time Base and the Oscillator to be investigated as shown in Fig. 14. Switch on the Time Base and adjust the frequency by means of the condenser and rheostat until it is an exact sub-multiple of the frequency of the oscillator, when a stationary pattern showing the wave-form will appear.

Should the wave-form be impure, changes made to the grid bias, etc., will have their resultant effects thrown upon the screen.

Conclusion.

The foregoing remarks deal with a single application of the Cathode Ray Oscillograph, but it is believed that sufficient has been written to indicate that the instrument may be of very great use for a wide range of investigations.

The author wishes to express his thanks for many valuable suggestions received from various sources.

A short bibliography is appended for the benefit of those who may desire to study the subject more fully.

O. S. Puckle.

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SHORT WAVE PROPAGATION

It is pointed out in the following article that the band of frequencies involved in radio transmission can be divided into two classes :—

(a) *Those frequencies corresponding to wavelengths below* 200 *metres, and which are termed short waves.*

(b) *Those frequencies corresponding to wavelengths lying between* 200 *metres and the audic frequencies which are termed long waves.*

Totally differently principles are involved in the propagation of these two types of waves, and the results which may be expected are outlined in a simple manner below.

MANY people have considerable difficulty in reconciling long distance short wave communication with ideas of propagation phenomena gained by a knowledge of long wave working, and the following notes set the case out in a simple manner.

By short waves is meant that band of wavelengths where the waves are considered to be propagated in accordance with the theory of ionic refraction ; this theory can only be applied to those wavelengths where the electrons make many oscillations between collisions of electrons with molecules of air, and this time corresponds to a wavelength round about 200 metres.

Thus short waves concern communication on wavelengths well below 200 metres and the wavelengths near this latter value may be considered as forming a critical wave band which is the dividing line between long and short wave phenomena.

Before considering these short waves it will not be out of place to review briefly our ideas concerning the propagation of waves around the earth. Above the critical band of wavelengths mentioned we can consider that waves are propagated as if bound by the conductors of a transmission line. That is to say, the earth is one conductor and the Heaviside layer another, and the waves travel in the homogeneous insulating medium between these boundaries, and thus we conceive the propagation of waves to follow the ordinary transmission line laws. With this type of transmission the distance it is possible to communicate depends only upon attenuation, for the conception of the Heaviside layer and earth as a spherical transmission line is sufficient to explain the bending of the waves around the whole extent of the surface of the earth. Of course radiation from a long wave aerial may involve an upward ray as well as the horizontal or surface ray. In this case the ray which is sent out from a transmitter upwards, when it meets the upper layer is reflected because the layer is almost a perfect conductor and interference effects from this ray with the surface ray may produce distortion, such for instance as the well-known night effects. In general, however, the surface ray is the only one which need be considered, and therefore since the distance of communication is a function only of attenuation and not of bending, the distance it is possible to communicate with a given power will be proportional to the wavelength or rather the wavelength squared. For it is losses in the equivalent transmission line which cause attenuation and since the resistance of a conductor is proportional to frequency squared, the attenuation falls off as the wavelength increases, and thus the curve of distance of communication against wavelength for a given equivalent input is very much as shown by the right hand part of the curve in Fig 1. When wavelengths of 10,000 metres and upwards are reached, it is then possible with normal power to communicate the maximum possible distance on earth, namely, half the earth's circumference. It is not suggested by this that 16,000 metres is the longest wave necessary for communication as longer waves give still more reliable communication at the greatest distance.

Below the critical wave band mentioned, we cannot regard the earth and Heaviside layer as two conducting surfaces because of the very high frequencies involved. The earth is a bad conductor and the Heaviside layer becomes a bad insulating medium. We must conceive the earth therefore as a bad conducting surface in which there will be a considerable loss of waves passing over its surface. The Heaviside layer must now be conceived, not as presenting a suddenly conducting surface, but as an ionised medium in which the ionisation is not constant but increases as the height of the layer increases from the earth. Due to this effect of a gradient in the medium, any wave which is directed at it will not be reflected but penetrates, and because of the gradient of the layer it gets bent, and as long as the gradient increases, the bending will increase. Thus in our conception of radiation from a short wave transmitting aerial we conceive that proportion of energy being transmitted horizontally as being dissipated by earth losses and rays which are being directed from the transmitter at upward angles, as penetrating the upper layer to different degrees depending upon their angle, these rays being bent in their passage through the layer because of the gradient, so much so that in many cases the ray will be returned to earth at some distance from the original source of disturbance. Thus in short waves horizontal, or the surface ray as it is called is of no use for medium and long distance communication but a ray which leaves the transmitter at some upward angle will be used. Hence the chief features for the propagation of short waves over long distances will be those which concern this bending action as well as attenuation. The particular angle which gives the best results is not an easy matter to make a definite statement upon, but it is fairly certain that high angle radiation even if not detrimental is of no value and there is strong evidence that the most useful energy is that which leaves the aerial at a very shallow zenithal angle, just sufficient to avoid earth losses. Hence the tendency of modern designs of short wave aerials, is to avoid those forms which give high angle radiation, such as the harmonic aerial, and to provide forms which propagate a large amount of their total energy at a shallow angle, such as the Franklin Multiple Aerial. Medium and long distance communication on short waves therefore necessitates three conditions being fulfilled.

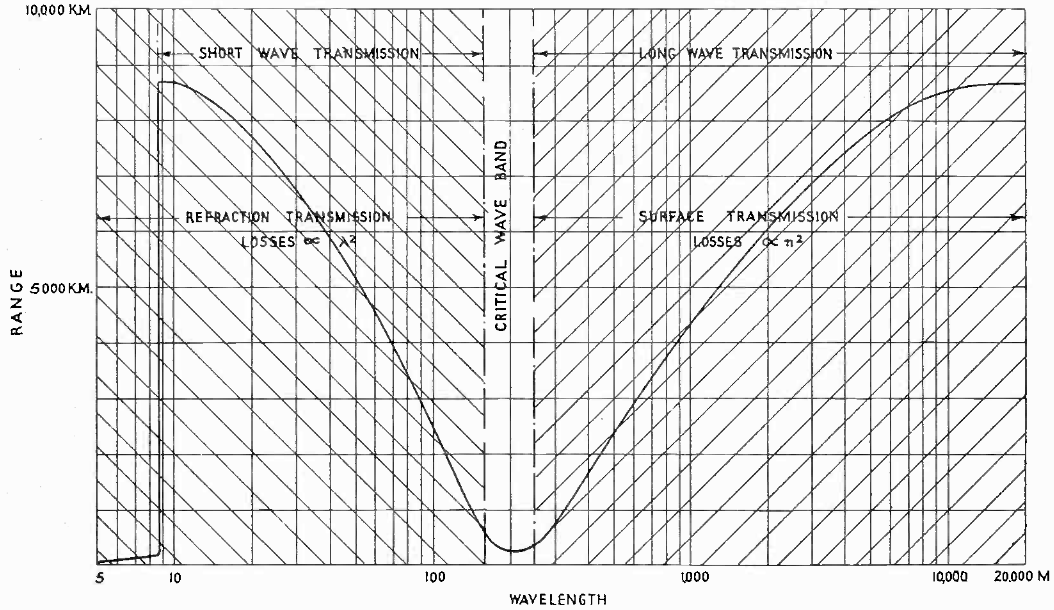
(1) that the attenuation through the layer should be small.

(2) That the bending should be sufficient.

(3) That the power should be radiated at the proper zenithal angle.

Attenuation.

Considering attenuation, this is now not a function of the losses in the equivalent transmission line as it was for long waves, but becomes a question of absorption of the wave as it passes through the upper ionised layer, and it is found that attenuation is proportional, for daylight conditions anyway, to the square of the wavelength ; in fact exactly the reverse of the long wave attenuation. This is very analagous to the case of the leakage losses in a condenser which are greatest to D.C. and decrease as the frequency is raised. If the distance of communication depended only on attenuation, the curve for communication distance against wavelength would rise from the critical wavelength as the wavelength was decreased. But as the bending effect which will be considered next is equally important we reach a limiting value of short wavelength for communication on earth, below which the range suddenly falls off to the surface ray range. This is shown on the left hand of Fig. 1, where the minimum distance is shown to cut off abruptly at a wavelength near 10 metres.



This does not necessarily mean that 10 metres will be chosen for communication to the Antipodes, for one thing it is too near the critical value and secondly, half the earth is never all in intense daylight, and thus one rarely finds any communication in practice carried on at wavelengths below 14 metres.

The amount of attenuation is dependent upon the layer conditions and in general will be proportional to the amount of ionisation. Thus during the day attenuation will be greatest because ionisation is greatest. Again in summer the attenuation on any given wave will be greater than in winter for the same reason.

Bending.

Considering now the second feature, it was observed that the bending of the ray is a function of layer ionisation and what is more important, layer gradient ; and to a lesser extent on collision frequency (where the wavelength considered is getting near the critical waveband), and hence it is necessary to study the causes of layer alteration.

The upper layer is to be thought of as a deep belt of ionised gas round the earth in which there is an unceasing movement of electrons and molecules of gas. The ionised molecules are continually re-combining to form neutral particles and owing to the effects of the sun's rays there is a supply of constant ionised particles which vary in number at any particular section of the layer depending upon whether the sun is on that part of the layer or not. The effective ionisation is really the balance of these two effects and hence will be greater at any given point during the day than during the night. The ionisation in itself is not of such importance as the gradient of the ionisation through the layer. For however great the ionisation is, if there is no gradient there will be no bending. Although it is clear that the layer condition and hence the bending is dependent upon daylight and darkness, the alteration of bending effects need not necessarily be, and in fact are not coincident with day and night conditions ; but it is clear also that not only will the time of communication be a factor to consider, but position on earth and season. For instance at a pole in winter there is never any ionisation and hence no gradient, no bending and presumably no communication would be possible through such a region. If one considers the earth illuminated by the sun, one is accustomed to think of half the world being in daylight and half in darkness, with a small rim of twilight as the periphery. Further that the darkness period will graduate from the rim to a point behind the sphere, immediately opposite the sun, where it will be darkest. It should be pointed out, however, that from a bending point of view, although dawn is almost coincident with the " electrical dawn," " electrical night " comes down comparatively slowly and the darkest period from this point of view is at some time previous to the actual dawn.

We can explain the reason for this in the following manner. As can be imagined the outer layer of atmosphere is most rapidly affected by the sun's rays, and hence as soon as daylight appears, the sun ionises the outer layer first which has the immediate effect of steepening the gradient, and hence the bending. The penetration of the sun into the layer as the day goes on ionises the inner layers but the gradient balance is kept although the layer as a whole gets more ionised. Thus considerable bending of short waves takes place as soon as the sun rises and continues through the day. Note, however, as the sun rises to its zenith the attenuation will increase owing to the increase of ionisation of layer.

As the sun goes off the earth, the ionisation diminishes but since there is no reason for the outer layer to return to its original state very much quicker than any other layer, the gradient flattens, but very slowly.

The amount of bending will, of course, be a function of the wavelength as well as of the layer condition, and as previously stated, waves below 10 metres are not bent back sufficiently to come to earth again, even during the condition of steepest gradient, i.e. day. Thus with waves up to 10 metres our communication distance is limited to that of surface ray, a few miles, as all upward radiation is either lost in the upper layer or escapes through the layer into the outer atmosphere.

Short wave communication over great distance is carried on therefore on wavelengths above 10 metres, and since the best wavelength depends on layer condition it is clear that to select the correct wave involves a knowledge of layer conditions at the time, season and place being considered and it is outside the scope of this article to deal with it.

Before concluding it might not be out of place to mention the critical waveband. As can be imagined the transition from short wave propagation to long waves is not a sudden one but goes through a phase whose condition shows certain characteristics of both types. On wavelengths lying in this region, between 150 and 300 metres communication is extremely bad. This is owing as mentioned previously, to the collision period between molecules of air and electrons coinciding with the period of the waves pass through the medium and presumably somewhat analagous to a resonance effect in the layer where all the energy of the applied wave is used up in creating internal losses in the layer. Hence one is confined to communication by surface ray and as this has a small range at these wavelengths, the band is only suitable for broadcast purposes, where the object should be to serve a limited area without interfering with the areas beyond.

A. W. LADNER.

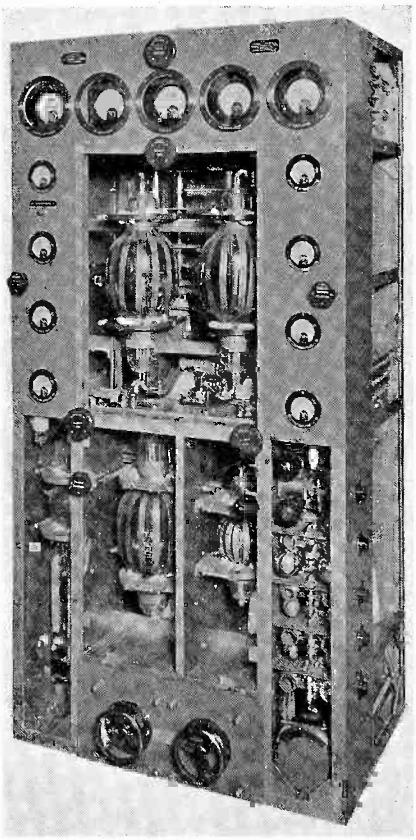
MARCONI NEWS AND NOTES

MARCHESE MARCONI TELEPHONES OVER 9,000 MILES FROM HIS YACHT TO AUSTRALIA

An important new advance in marine wireless telephony has been marked by the success of the experiments recently conducted by Marchese Marconi, in which he carried on conversations from his yacht "Elettra" in the Mediterranean with telephone subscribers in Sydney (New South Wales), London, Montreal, Bombay, Cape Town, New York, Buenos Aires, and Rio de Janeiro.

The first of these conversations, which have aroused world-wide interest among wireless technicians and in the Press, took place on March 21st, when Marchese Marconi spoke, from the S.Y. "Elettra" off Genoa, with Mr. E. T. Fisk, Managing Director of Amalgamated Wireless (Australasia), Ltd., and others at Sydney, over a distance of about 9,000 miles—more than three times the distance of the previous record for a telephone conversation between a ship and a land telephone subscriber.

Two-way conversation from a ship over such a great distance is a remarkable achievement and indicates the efficiency of the new wireless telephone equipment used by Marchese Marconi. This apparatus was constructed at the Marconi Works, Chelmsford, and has been developed to provide an efficient wireless telephone installation to meet the growing demand for a wireless telephone service connecting ships at sea with the land telephone network.



The short-wave telephone transmitter used by Marchese Marconi.

Features of the Installation.

This new short wave telephone installation operates on a wavelength of about 30 metres with a power of 2 kilowatts. A number of new features have been incorporated in the design to ensure the greatest efficiency of operation.

One of the most important of these is the provision of a special valve drive, corrected for temperature variation, which, while equal in constancy to a crystal drive, eliminates the disadvantages inherent in the crystal type of control.

The complete installation is compact and can be placed in an ordinary cabin. It is simple in operation and promises to provide an efficient wireless telephone service for ships at sea over almost any distance.

"Conversation Remarkably Clear."

In the following telegram received from Mr. E. T. Fisk after his conversation with Marchese Marconi the capabilities of the new set are indicated :—

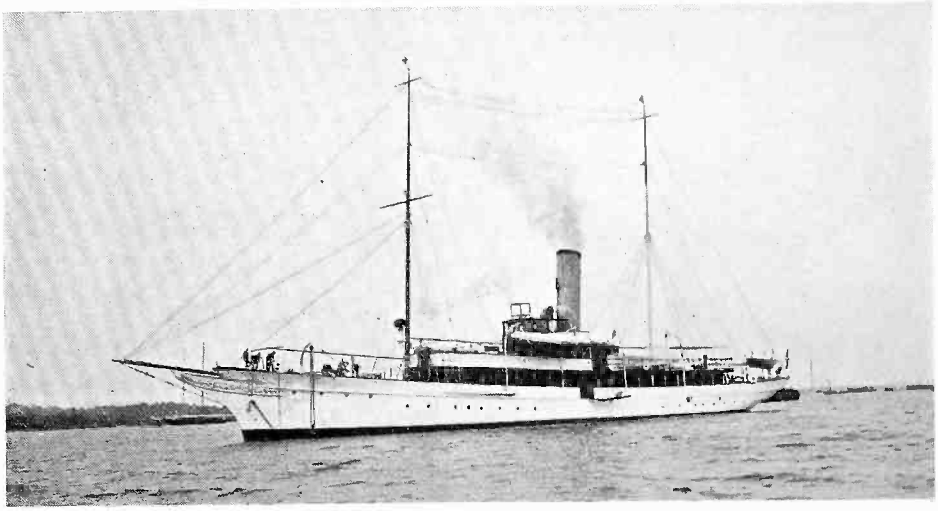
> "My conversation from Sydney with Marchese Marconi on board his yacht "Elettra" at Genoa has caused great interest here. The conversation was remarkably clear and as easy as talking by ordinary telephone between Sydney and the suburbs. This result is particularly notable because Marchese Marconi's yacht is a vessel of only seven hundred tons, and consequently both the power and the antennæ which could be employed on board were severely limited. This is a world's record for duplex radiotelephone conversation between ship and land."

Opening the Sydney Exhibition.

In the course of his wireless telephone talk with Australia Marchese Marconi received a request to take part in the opening of the Annual Electrical and Wireless Exhibition at Sydney by sending a wireless signal from the "Elettra" in the Mediterranean to Sydney to operate a relay which would switch on the lights in Sydney City Hall and so open the Exhibition. This he agreed to do and the demonstration took place on March 26th, proving most impressive.

By means of the wireless telephone set on the S.Y. "Elettra," Marchese Marconi also spoke to the chairman of the Exhibition. The following message from Marchese Marconi to the Exhibition explains how the operation of lighting the lamps from the Mediterranean was achieved.

> "It affords me great pleasure to perform the ceremony of officially lighting the symbol of the Red Seal Scheme inaugurated by the Electrical and Radio Development Association in New South Wales.
>
> "The switches for lighting the Sydney City Hall will be operated by wireless from the yacht 'Elettra,' which is at present in the Mediterranean at Genoa.
>
> "By the act of depressing a key on board the 'Elettra' I shall automatically release a train of waves from the Beam wireless station in England, which will be practically instantaneously received at Rockbank, Victoria.
>
> "The impulse will then be relayed automatically through 550 miles of overland wire to the Sydney City Hall where it will cause the power to be switched on to the lights.
>
> "It is not more than thirty years since I transmitted the first faint wireless signals across the Atlantic Ocean and to-day we demonstrate that it is possible by wireless to bring powerful currents into operation at the other ends of the earth.



S.Y. "Elettra."

> "On your chairman's request which will be transmitted to me by Beam wireless I shall set in motion the apparatus on the 'Elettra' which will automatically actuate the switches in the Sydney City Hall and so inaugurate the Red Seal Scheme.
>
> "I heartily congratulate Australia on the strides made there during recent years in world-wide wireless communication."

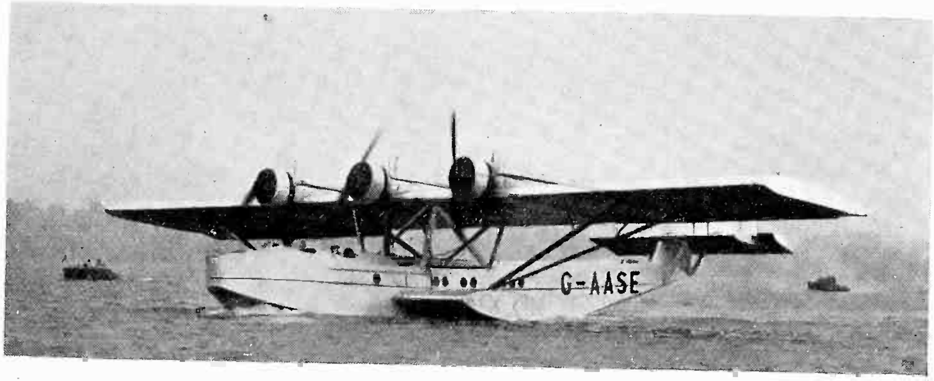
Following the opening of the Exhibition, Marchese Marconi spoke direct from the S.Y. "Elettra" to Sydney, and Reuter's correspondent on board the yacht was also handed the telephone and conveyed oral greetings to a gathering of journalists in Sydney.

Particulars of the pioneer work of Marconi's Wireless Telegraph Co., Ltd., and the Marconi International Marine Communication Co., Ltd., in wireless telephony at sea will be found in No. 12 of the MARCONI REVIEW.

Wireless for Air Yacht.

The three-engined Supermarine Metal Monoplane flying boat just purchased by the Hon. A. E. Guiness, the first of its kind built in Great Britain for a private owner, carries a comprehensive Marconi installation.

This air-yacht, which has a cruising speed of 100 miles per hour, will normally carry a crew of three and six passengers. The Marconi equipment consists of a powerful transmitter and receiver, a Direction Finder, and a broadcast receiver. The transmitter and receiver are of the Marconi $\frac{1}{2}$-kilowatt A.D.8 type which will provide reliable communication between the air-yacht and aerodromes, coast stations, and



The Hon. A. E. Guiness' supermarine air yacht, equipped with Marconi apparatus.

vessels on the high seas, up to 400 miles under normal conditions either on telephony or telegraphy.

The Direction Finder is the trusted friend of aerial navigators in fog or under conditions of bad visibility and the fitting of a Marconi Direction Finder Type A.D.16 illustrates the thoroughness with which the navigation equipment of this air-yacht has been studied.

The broadcast receiver is a Marconiphone Type 35 instrument which will provide an enjoyable source of entertainment for the crew and passengers and will enable them to choose the best of the broadcast programmes within a wide range.

Wireless communication can take place either during flight or when the machine is resting on the water. To meet both purposes two aerials are provided, one of the trailing type for use in the air and the other of the fixed type, attached between the wings, for use on the water.

This is the second air yacht owned by the Hon. A. E. Guiness to be equipped with wireless apparatus by the Marconi Company, an A.D.6 transmitter and receiver having been installed in his Supermarine " Solent " flying boat in 1927.