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THE MARCONI-MATHIEU METHOD OF MULTIPLEX SIGNALLING

GENERAL DESCRIPTION

In the March number of THE MARCONI REVIEW a short preliminary description of the "Marconi-Mathieu Multiplex System" was given.

In the following article a more complete and detailed account is given of the above system, and the general principles on which the transmitter and receiver work are described in full.

A technical description of the apparatus will follow at a later date.

THIS system enables both telegraphy and telephony to be carried on simultaneously at the same stations using the same aerial, feeder system and plant without detriment to the quality of the telephony or telegraphy.

Both services, telephony and telegraphy, work together without interference with each other.

The extra cost of adding the equipment to an existing Beam Station or to that of an ordinary simplex new installation, is unimportant compared with the heavy cost which would be entailed by erecting separate stations capable of being used for one of the services only.

The present available standard apparatus provides for one telephone circuit and two telegraph high-speed channels. The commercial speed of these telegraph channels is between 100 and 200 words. The telephone channel enables communication from subscriber to subscriber and incorporates voice operating devices effectively preventing echo and singing.

Transmitter Modulation.

For Multiplex working the standard transmitter is equipped with a modulating circuit consisting of a sub-sub-modulator, a sub-modulator, and two main modulating

valves working on the anode choke modulating system. This additional equipment is in every point identical to a Broadcasting modulating equipment, and provides for a 90 per cent. distortionless modulation of the transmitter. In these conditions the normal rating of the transmitter is 10 kw. to the anode of the main amplifier and 10 kw. to the main absorbing valve. With an even distribution of the total modulation, each channel will then modulate the transmitter to the extent of 30 per cent.

The carrier power of 10 kw. is common to all three channels and therefore, for comparison purposes, the power of each channel corresponds to that of a 10 kw. simplex transmitter modulated 30 per cent., and the effect at the receiving end, therefore, corresponds to these conditions.

For the purpose of avoiding interference between the telephone and telegraph channels, and also to decrease the power required to convey intelligibility in the telephone channel, which is mainly due to the L.F. component of the speeds, the telephone channel frequencies are limited between 400 and 3,000 cycles. The first telegraph channel is obtained by keying a 7,000 channel generator and the second telegraph channel by keying a 9,000 generator, all the frequencies are superimposed and used as total modulation power of the transmitter.

It is obvious that under these three simultaneous modulations the transmitter radiation is as follows: the carrier wave; two waves corresponding to the upper and lower side bands produced by the 9,000 cycles telegraph channel modulation; two waves corresponding to the upper and lower side bands due to the 7,000 cycles channel modulation, and two side bands of modulation caused by the telephone channel.

Allowing a 1,000 cycles margin for adjustment on either side, such a multiplex transmitter occupies an effective band of 20,000 cycles.

The auxiliary Multiplex transmitting gear consists of three small valve generators, adjusted to transmit respectively 9,000, 7,000 and 1,000 cycles. The first two are used for telegraph working, and the 1,000 cycles generator for the adjustment of the telephone channel, but this could also be used as a third telegraph channel in replacement of the telephone channel.

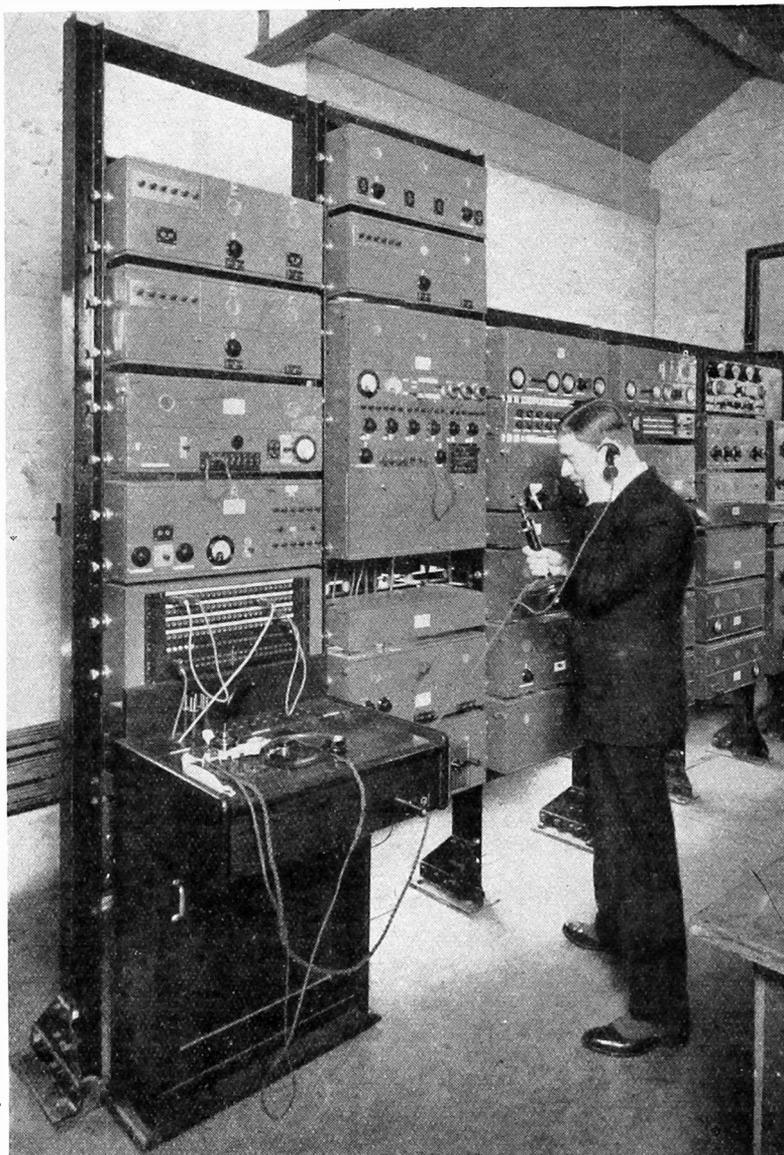
Keying on Telegraphy.

The system used for the keying of these generators secures an equal time of spacing and marking current at all speeds, using both contacts of a relay set on its neutral mechanical bias. The circuits provide for an output free from key-clicks and harmonics, and are covered by patents.

Means are provided for the adjustment of the output of these generators and also to check them without causing any interference. The normal output of each of these generators is 1 mw. into an impedance of 900 ohms, which has been chosen arbitrarily as zero level for all the adjustments.

The Marconi-Mathieu Method of Multiplex Signalling.

The adjustment and distribution of the modulation between the channels is



obtained by working the output of these three generators into a composite unit through calibrated resistance networks.

It is obvious that it is not necessary to make use of these three channels always, and that if desired one single channel using the complete modulation can be used, or if traffic conditions do not justify the use of two telegraph channels at certain hours,

one of the telegraph channels can be switched off, leaving a 45 per cent. modulation for the telephone and 45 per cent. modulation for the telegraph channel utilized, or any of the distribution of the 90 per cent. modulation between these two channels.

Of course, normally the 1,000 cycles channel is replaced by the telephonic modulation, and to that effect the auxiliary apparatus also provides for filters limiting the speech channel frequencies between 400 and 3,000 cycles, and a neon-tube amplitude limiting device preventing over-modulation of the telephone channel, by accidental shouting or mistakes made in handling the telephone landlines circuits.

At first sight it might appear that the result obtainable on the telegraph channel, with 10 kw. carrier modulated at 30 per cent., would be inferior to that obtained with a transmitter working simplex at 18 kw. input, keyed at the usual 100 per cent. absorption method; full power being sent for marking and no radiation at all in spacing, but our experience has proved, over and over again, that the telegraph multiplex channel of the new system is at least as reliable and even often more reliable than the old simplex system.

Elimination of Fading.

This is due to the pronounced anti-fading property of the new system, which is based on the well-known selective fading properties observed nearly at all times in all our commercial short wave communication services.

By selective fading is meant the fact that the same messages sent simultaneously by two transmitters working with small differences of frequencies, practically never fade simultaneously.

“Fading” is used in this case to mean the rapid phenomena observed continuously during the normal conditions of propagation, and not the complete fading of the signal due to the action of magnetic storms.

The modulation of the transmitter at 7,000 cycles or 9,000 cycles is equivalent to the sending of the same messages by two transmitters working 14,000 or 18,000 cycles apart, and assuming a steady and constant carrier, it is sufficient that one of these side bands exists to get the signals. In effect, the carrier itself is affected by fading and when fading to nothing, or to a very small value, there would be no signal after detection, even if the two side bands of the telegraph channel should be strong at the same instant.

Treatment of Side Bands and Carrier.

To avoid this, in the Marconi-Mathieu Multiplex System, the transmitted carrier wave is suppressed at the receiving end, then reintroduced by means of a steady constant generator of exactly the same frequency.

The anti-fading properties of the system are strikingly demonstrated when using the multiplex receiver, which permits an independent reception of either the upper

side bands or the lower side bands of either of the two telegraph channels, thus allowing a comparison of the results obtainable on one of the side bands alone with both used simultaneously.

The Receiver.

The multiplex receiver is of the double heterodyne type and involves many special and new features, which are covered by patents.

It is characterised by the fact that an harmonic of the generator reintroducing the suppressed carrier is used as second heterodyne between the first and second intermediate band filter amplifiers, and in such a way that the resulting beat frequency of that harmonic, with the first new carrier wave due to the action of the first heterodyne of the original carrier, corresponds exactly to the fundamental frequency of that generator, thus permitting a zero beat method of adjustment for the whole receiver, involving only the adjustment of the first heterodyne.

This invention renders the system commercial and converts an otherwise hopelessly complex handling into simplicity itself.

Key-clicks, due to the telegraph channels, have been completely eliminated from the telephone channel, by separating, before detection, the telephone channel and the telegraph channel at high frequency, after they have been heterodyned for the first time and amplified together.

After the second frequency change, the upper side bands and lower side bands of the two telegraph channels are separated and amplified separately. The suppression of the carrier occurs also at that stage.

The separation of the telegraph channels, both in each of the side bands, is effected after the reintroduction of the carrier, by means of band filter amplifiers, which width of band is sufficiently large to allow a speed of 300 w.p.m. and the adjustment of the zero beat without creating interference.

The types of band filter amplifiers are the same as those used for the standard beam receivers ; they have the advantage of having an extremely small noise level and are capable of handling, without distortion or saturation, a very large amplitude of signal.

The adjustment of high frequency amplification of the receiver and that of the low frequency amplification of the telephone channel, is automatic and is effected by the variation of an attenuating distortionless network controlled by mechanical relays.

These automatic devices are remarkably reliable. They require very little attention and keep their adjustment for months on end ; they possess the enormous advantage of introducing no reaction in the circuits, no extra noise level, no distortion and no change in the characteristics of the valves.

The telegraph direct current bridge and limiting device are in every respect similar to that of the standard beam telegraph receivers, which are giving such good service on all the Marconi Beam Stations. They only differ in the fact that they provide for the combination of the upper and lower side band signals of each channel.

Description of the Receiver.

The receiver consists of two stages of H.F. amplification amplifying together all the original waves, followed by a first frequency change circuit. The heterodyne of this circuit has been made very stable by the use of a special driving circuit working into a separating valve. The output of the modulating valve of this circuit works into a four-stage band filter amplifier, which middle frequency is 180,000 cycles with a band of 10,000 on either side of that frequency.

The separation of the telephone and telegraph channels is started by means of coupling valves preventing reaction between the circuits and working respectively, one into a similar 20,000 cycles band filter for the telegraph channels, and the other into two very selective stage filter amplifiers having a band of only 3,000 cycles on either side of the new carrier wave and securing the separation of the telephone from the telegraph channel.

The telephone detectors are diode valves working in push-pull and without high tension. The circuit is such that all possible induction originated by the auxiliary apparatus of the telegraph channels, as the mechanical relays, check undulator, sounders, etc., are effectively balanced before they reach the input of the L.F. amplifier.

This detector circuit also provides for the separation of the A.C. alternating current component from the direct current component, due to the demodulation process. The direct current impulses are smoothed by filters, then amplified by a special direct current amplifier, which output is used for the working of the relays actuating the artificial lines of the automatic gain controls.

The L.F. amplification or receiving repeater consists of two stages of amplification, having a total gain of about 40 T.U. and a maximum distortionless output of plus 10 T.U.

The gain of the two stage direct high frequency amplifier runs from 5 to 20 T.U. according to the wavelength used.

The maximum gain of the H.F. intermediate amplifier, common to all channels, is about 80 T.U.

The automatic device controlling the H.F. amplification operates on the input of the coupling valve mentioned above. The description of this automatic system will be given later.

Returning to the telegraph channel we will repeat that the output of the coupling valves of the first intermediate band amplifier is working through an intermediate band filter into the grid circuit of the second modulating valves, where all the waves are made to beat again with the 5th harmonic of the reintroducing carrier generator.

The output of this modulating valve works into filters, which purpose is to separate the upper side bands and the lower side bands of the telegraph channels; to suppress the new carrier wave and to very strongly attenuate all the frequencies of the telephone channel.

The frequency generated by the carrier reintroducer channel is 30,000 cycles. Its 5th harmonic being 150,000 cycles, it will be seen that when subtracting this 5th harmonic from the 180,000 first new carrier, it reproduces a wave of 30,000 cycles.

The zero beat method consists of coupling simultaneously the input circuit of a detector to the output of the second modulating valve and to that of the carrier reintroducer circuit.

It can be seen that in these conditions when the original carrier is being changed exactly to 180,000 cycles by the action of the first heterodyne, a zero beat note will occur in the output of that detector, thus permitting the adjustment of the receiver.

The upper side bands and lower side bands of the telegraph channels, once separated, are amplified separately by the upper side bands and lower side bands band filter amplifiers which are designed for a width of 3,000 cycles, with a middle frequency of respectively 38,000 cycles and 22,000 cycles.

The gain of these amplifiers is approximately 50 T.U. These two amplifiers are terminated by push-pull detectors where the carrier is reintroduced by means of coupling valves which prevent any back reaction towards the carrier reintroducer generator. The output of these coupling valves work into very loosely coupled low-damping condenser circuits, tuned sharply to 30,000 cycles and arranged to be used as a wavemeter for the adjustment and checking of the frequency generated by the reintroduced carrier generator.

The effect of reintroducing the suppressed carrier is to reproduce the 7,000 and 9,000 cycles modulation impressed on the transmitter on both side band circuits. Their respective separation is then obtained by means of filters associated with the output circuit of the detectors.

The output of these filters works into 7,000 and 9,000 cycles valve amplifiers and are terminated by a final detector valve the D.C. components from which feed the D.C. and limiting circuit of the recording units.

G. A. MATHIEU.

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MARCONI RECEIVERS FOR TIME SIGNALS AND PRESS BULLETINS

II.—R.P.II

In the last issue of THE MARCONI REVIEW, an account of a receiver—Type R.G.12—for the reception of press messages was given. In this article a description of the Type R.P.II receiver, which is primarily designed for the reception of time signals, will serve to show in what respects the design of receivers for the above mentioned purposes differ from one another.

Time signal reception is becoming of increasing use, partly for the synchronisation of widely separated activities and partly for the accurate determination of longitude, etc.

Many stations transmit time signals of great accuracy, and it will be seen therefore that the wireless method of obtaining accurate time signals is far more practicable than any of the older methods and is becoming of almost universal use.

The R.P.II receiver is sufficiently portable to be used by survey parties and is built in such a way that it can resist extremes of climatic conditions.

THE type R.P.II receiver has been designed for the reception of time signals from high power long wave stations. The outstanding features of the receiver are as follows:—

1. Portability.
2. Ability to withstand rough usage in any climate.
3. Great selectivity.
4. Low filament consumption.

The receiver itself uses four valves of the D.E.3B type, performing the functions of detector, note filter, note magnifier, and local oscillator respectively.

A phasing unit, separate to the receiver, is also provided to enable directional selection of stations to be more efficiently achieved.

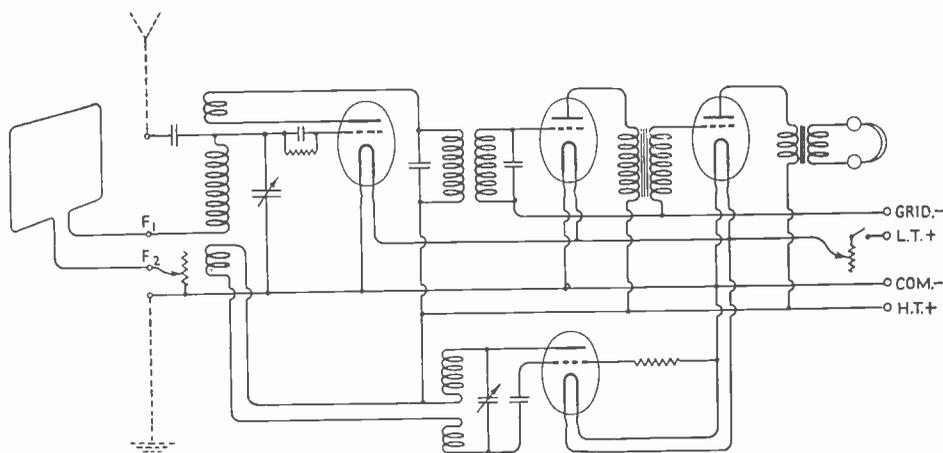
The receiver is intended for normal use with a frame aerial with no earth connection to the set, but terminals are provided for connecting an open aerial and earth. In the latter case the frame must also be connected to the set to complete the circuits. The receiver is far more selective with the frame than with the open aerial, but signals are naturally stronger in the second case.

In the case of cardioid reception with the phasing unit, a vertical aerial has, of course, to be used. This may be of any convenient length, a length of about 30 feet being generally sufficient to give a cardioid diagram.

The waverange of the receiver is from 15,000 to 22,000 metres, and this range is covered in two steps. A modification of the R.P.II receiver has been designed to cover an extended waverange of 10,000 to 22,000 metres, and this is termed the R.P.IIa receiver.

The Receiver.

A simplified diagram of the receiver is given below.



The aerial tuning inductance is contained partly in the frame aerial and partly in a coil in the receiver. This coil is provided for the purpose of introducing reaction into the aerial circuit, and also the signal from the local oscillator. Both the reaction coil and the local oscillator coupling coil are fixed rigidly to the aerial coil and the degree of reaction is controlled by a non-inductive helical resistance in the frame aerial circuit. This method of controlling reaction has the advantage of permitting a very gentle "slide in" to reaction and consequently allows reaction to be used to an extent to which it would not otherwise be permissible.

Grid leak rectification is used, and it is found that this does not give rise to any blocking of the rectifier grid as the signals induced in the frame are so small, and no high frequency magnification is used on the set.

Tuning is accomplished on the lower of the two waveranges by means of a .001 mfd. variable condenser in the aerial circuit, a fixed condenser of .001 mfd. being placed in parallel with this on the second range. The two ranges are selected by means of a barrel switch which is operated from a handle placed in front of the set.

The note filter stage employs the standard circuit and consists of an air core transformer with its grid winding tuned to a frequency of 1,200 cycles by a mica dielectric condenser of .01 mfd. capacity.

The note magnifier is transformer coupled to the preceding stage and is normal in design.

The local oscillator employs the usual circuit, and has its constants so arranged that its tuning condenser keeps roughly in step with the aerial tuning condenser when giving a beat note of 1,200 cycles. The coupling coil to the aerial circuit is taken from the earth end of the local oscillator inductance, and since it consists only of a few turns the coupling to the aerial circuit is purely magnetic, and this fact, combined with the fact that the local oscillator circuit is tuned by varying its capacity only, ensures an equal strength of oscillator signal over the whole of the range. A fixed condenser is switched in for the upper range, the same switch operating both the aerial and oscillator circuits in this respect.

Telephones.

Low resistance telephones are used with this receiver, and these are arranged to have a natural period of 1,200 cycles. In this way a considerable gain in sensitivity and selectivity will result, as the optima of the note filter stage and of the telephones coincide.

The telephones can either be connected directly on to the secondary winding of the transformer, or can be connected in series with the contacts of a chronometer. This last method is resorted to in the case where the "vernier" system of time signal measurements is used. Assuming that the contacts of the chronometer open once a second, and that the chronometer and telephones are in series, the chronometer and time signal would be in step when the dot of the time signal was not heard in the telephones for the first time. If the contacts of the chronometer are arranged to close once a second, the chronometer and telephones will be connected in parallel. Means are provided in the R.P.11 receiver to enable either of these two systems to be employed. In this way it will be seen that very accurate time signal determinations can be made.

Phasing Unit.

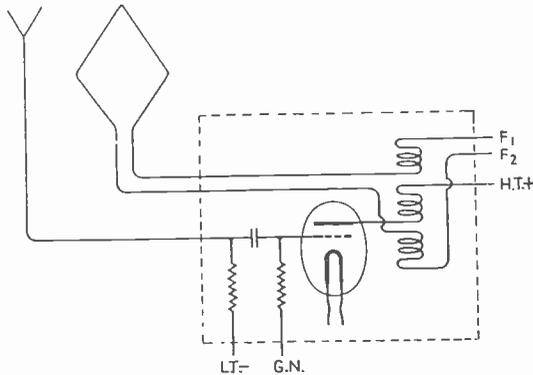
So far we have only considered the receiver as used with an open aerial giving a circular polar diagram, or with a simple frame giving a figure-of-eight polar diagram. An external phasing unit is provided for use with the receiver and consists of a coupling valve, coupling coils from the vertical to the frame aerial and an intensity control to enable a correct cardioid diagram to be obtained.

A simplified diagram of connections of the phasing unit is given below, and it will be seen to be almost identical in design to the phasing unit described in connection with the R.G.12 receiver. Two leads are taken from the frame aerial to the phasing unit, where they pass through the two coils coupling into the output coil from the coupling valve. The other ends of the coils are connected to the terminals F1 and F2 of the receiver. The output coil from the coupling valve is variably

coupled to the two frame aerial coils to enable strength control of the vertical aerial signals to be obtained.

Batteries.

Either two Siemens 66-volt dry batteries are provided for use with the receiver, or eight 15 volt units of the inert type. These batteries are tapped to enable the correct working voltage for the valves to be obtained.



The low tension voltage is 2.8 and the total filament current is .24 ampere. A dry battery can be used with the set, which is a great advantage where questions of portability are concerned. A filament voltmeter is provided on the front of the set and a red mark is placed on the scale of this at the correct filament voltage.

A grid bias battery of 1.5 volts is required. This can take the form of a very small dry cell.

All the above batteries can be contained conveniently in one box.

R.P.11a Receiver.

This receiver consists of the R.P.11 receiver together with such modifications as have been found necessary to increase the waverange of the R.P.11 to 10,000 to 22,000 metres.

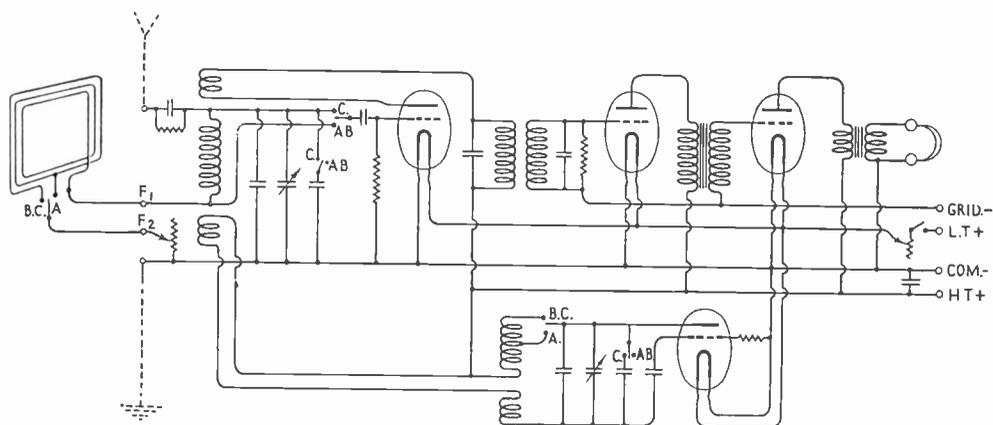
The above waverange is covered in three steps, with ranges of approximately 10,000-14,000 metres, 13,000-18,000 metres and 17,000-22,000 metres. The switching is effected by a barrel switch having four positions, the fourth position being for "Off."

The ranges are obtained in the following manner :—

- Range 1. 80 turns only of the standard R.P.11 frame are across the receiver input, and this proportion of the complete frame is tuned by a .001 mfd. variable condenser.
- Range 2. The whole frame of the R.P.11 is used, and this is tuned by the same condenser.

Range 3. An added condenser is placed in parallel with the original condenser.

A compensating device is included in the frame leads to be used in the case of cardioid reception with the phasing unit. This consists of two small added inductances which are placed in the frame leads when using figure-of-eight reception.



These are automatically removed when the phasing unit is plugged into circuit, and serve to keep the calibration of the instrument constant with or without the phasing unit attached to the set.

Selectivity.

The selectivity of the R.P.II receiver due to the use of H.F. selection and note filtering is such that either of two stations of equal signal strength and lying in the same direction can be separated if their frequencies differ from each other by about 200 cycles per second. At 15,000 metres the receiver can, therefore, separate two stations only 150 metres apart, whilst at 20,000 metres the receiver can select between two stations 270 metres apart.

Equipment.

For convenience of transport the standard equipment is divided into four units.

1. The frame aerial.
2. The receiver.
3. The H.T. battery box.
4. The L.T. battery box and spares.

In cases where the phasing unit is used, this forms an additional item to the standard equipment.

The receiver and phasing unit are contained in separate watertight steel cases in which suitable provision is made for ventilation.

THE MEASUREMENT OF SIGNAL STRENGTH

HISTORICAL SURVEY

In a later article to be published in THE MARCONI REVIEW a full description will be given of an instrument designed for the accurate measurement of signal strengths by the Marconi Company.

Many attempts have been made of late years to evolve scientific means of experimentally determining transmitter field intensities, partly with a view to obtaining experimental confirmation of transmission theories and partly to decide as to the best methods of obtaining as perfect a system of world-wide radio communication as possible.

A brief outline of these attempts is given below, together with a description of one of the first signal strength measurers used by the Marconi Company.

THE first wireless measurements of signal strength with any claim to accuracy were made by Duddell and Taylor in 1905 (Jour. I.E.E. 1905, Vol. 35, p. 321. Wireless Telegraph Measurements, W. Duddell & J. E. Taylor). A Duddell thermo-ammeter was used at the receiver end, and the currents in the receiver aerial were measured.

In 1909 Dr. L. W. Austin began a series of experiments over long distances using a receiver with hot wire and thermo-electric ammeters by which the received currents were measured (Bulletin of the Bureau of Standards, Vol. 7, 1911). The results of these researches led to the final adoption of the semi-empirical Austin Cohen formula:

$$I_R = A \frac{I_s h_1 h_2 e^{-.0015 \frac{D}{\sqrt{\lambda}}}}{D}$$

where

I_R = current in receiver aerial

I_s = " " transmitter aerial

h_1 = height of receiver aerial

h_2 = height of transmitter aerial

λ = wavelength in kms.

D = distance between receiver and transmitter in kms.

Now Hertz had obtained theoretically the fact that in the case of an oscillator of moment ϕ and of wavelength λ , either the magnetic or electric intensity was given by

$$E \propto \frac{\phi m^2}{r}$$

where

$$m = \frac{2\pi}{\lambda}$$

and $r =$ distance from oscillator to point under consideration,
and it can be shown quite easily that

$$E \propto \frac{\phi m^2}{r} \propto \frac{I_s h_1}{\lambda D}$$

which agrees with the Austin Cohen formula except in so far as the exponential factor is concerned. Hertz, however, assumed perfect conductivity for the earth, whereas in the actual case the earth has a conductivity appreciably differing from infinity.

In 1911—1912 Captain Round and Mr. Tremellen of the Marconi Company carried out a fairly extensive series of measurements on daily and annual variations of high power station signals at various places chiefly in connection with spark transmission.

In 1921 Vallauri published the first results on the use of the comparison method of measuring signals originally suggested and used by Eccles. In the instrument used by Vallauri two frame aerials at right angles to each other were used, one of which pointed in the direction of the received signals. Artificial signals were then induced into the other frame and the real signals compared with them.

Dr. L. W. Austin and E. B. Judson (Proc. I.R.E., Oct. 1924, Vol. 12) suggested a method for the determination of signal strengths using aural comparison of the received signal with an audio frequency signal of known intensity. A 1,000 \sim fork was used as the audio frequency source, and the E.M.F. generated by this was impressed on the telephones by a voltage divider. A thermo-milliammeter was used as the measuring device. An open aerial was used for the reception of the signals.

C. R. Englund (Proc. I.R.E., Feb. 1923, Vol. 11) and R. Bonn, C. R. Englund and H. T. Friis (Proc. I.R.E., Apr. 1923, Vol. 11) give an account of the apparatus used by them and consisting of a receiver band filter artificial line, valve voltmeter and local oscillator. The signals from the receiver and the local oscillator were equalised by means of the valve voltmeter, which latter had been previously calibrated. A loop aerial was used. The apparatus is stated to be capable of signal strength measurement of from 3.5 μ V/metre upwards.

The National Physical Laboratory published an account of the instrument used by them, in Jour. I.E.E., Apr. 1926, No. 317. In this article will also be found a very complete account of the difficulties of investigations of this nature.

In any signal strength measuring set, what is actually measured is the total E.M.F. in the receiving aerial system. What is required for calculation purposes is

The Measurement of Signal Strength.

the actual field strength in microvolts per meter. This transformation involves the measurement of—

1. Either the effective height of the aerial, in the case of a vertical aerial, or
2. The effective area in the case of a frame.

The effective height of any aerial system is very difficult to measure accurately. It would appear therefore that the use of a frame aerial presents the best solution of the problem.

The E.M.F. induced in a vertical aerial is in phase with the E.M.F. of the signal. The E.M.F. induced in a frame due to the magnetic component of the signal is in quadrature with the E.M.F. of the signal. A certain E.M.F. due to "vertical" effect is always present in such an aerial system and is in phase with the signal E.M.F. This introduces an out of phase component of E.M.F. which somewhat complicates the calculation of field strength.

It will be seen therefore that both aerial systems introduce difficulties in calculation of field strength, and we shall point out briefly how these difficulties are, to a certain extent, overcome in the apparatus used by the Marconi Company for the determination of signal intensities.

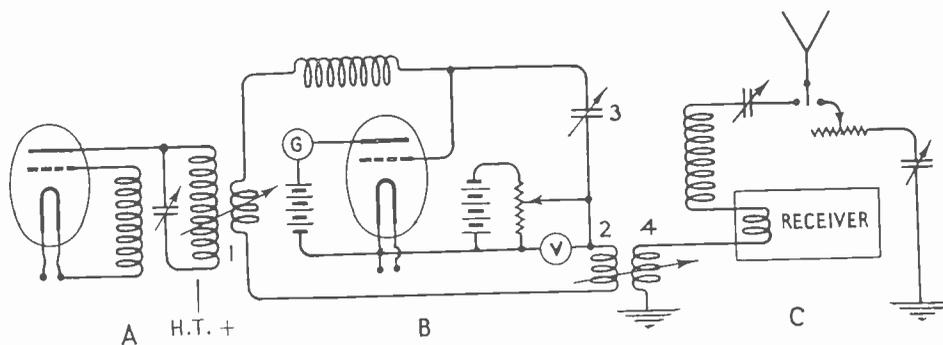


FIG. 1.

The instrument developed and used by the Marconi Company in 1921, while agreeing in some respects with Vallauri's apparatus, differed in many others. The results obtained with it were so consistent and helpful however, that a brief description is given below.

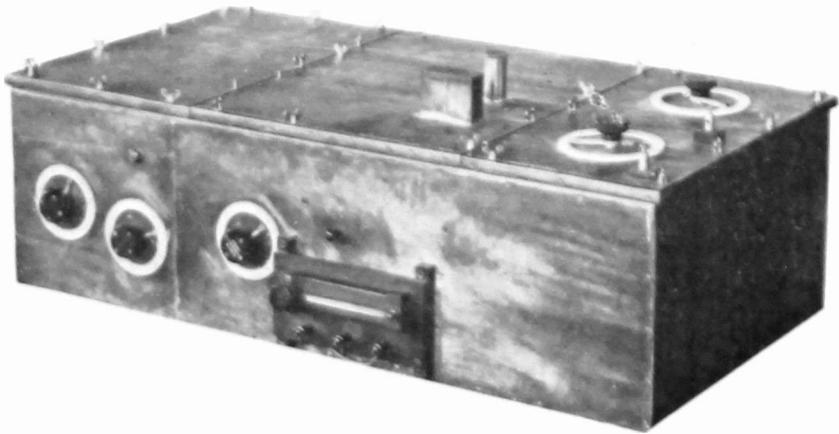
A diagram of connections of the signal strength measurer is shown above (Fig. 1). The method consists essentially in providing an artificial continuous wave signal of the same frequency as the signal to be measured, the intensity of which can be varied over wide limits and measured. This artificial wave signal can be introduced into the receiver aerial or into a dummy aerial having the same electrical constants.

The Measurement of Signal Strength

The strengths of the received signals in the dummy aerial caused by the artificial signal, and of those in the aerial caused by the incoming signal are equalised. The E.M.F. induced in the dummy aerial can be calculated and will give the E.M.F. of the real received signal.

The instrument measures, therefore, the intensity of E.M.F. induced by the signal in the aerial used. If the effective height of the aerial is known it is quite a simple matter to calculate the electric field strength in the incoming wave.

Referring to Fig. 1. The oscillator A is a simple tuned anode oscillator capable of wide frequency adjustment. A variable coupling coil (1) enables signals of the required voltage to be applied to the grid of the slide back valve. The current in



the coil (2) can be calculated if the voltage across the condenser (3) is known, this voltage is given by the reading of the slide back voltmeter, when the following relation holds:

$$I_{\max} = C p V_{\max}$$

where

$$I_{\max} = \text{required current}$$

$$C = \text{capacity of (3)}$$

$$p = 2\pi \times \text{frequency}$$

$$V = \text{voltmeter reading}$$

The artificial E.M.F. is then induced into the aerial circuit by means of the coil (2). The mutual inductance between (2) and (4) was measured on a low frequency method and checked at high frequencies.

In terms of the known quantities the E.M.F. induced in the aerial could be calculated from the formula

$$E = \frac{2.515 \text{ MCV}}{\lambda^2}$$

The Measurement of Signal Strength.

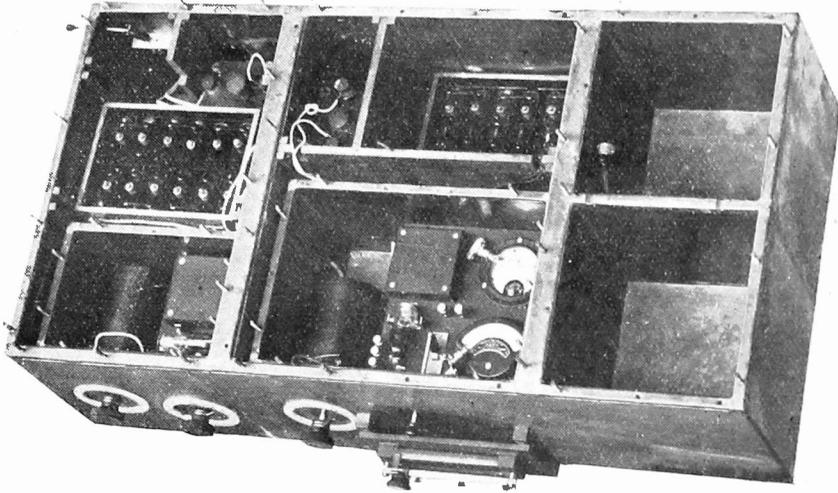
where

M is in microhenries

C is in microfarads

V is in volts

λ is wavelength in metres



Hence the E.M.F. induced in the dummy circuit or aerial, which is made equal to the E.M.F. induced by the signal in the aerial, can be calculated and the signal intensity found.

The two photographs show external and internal views of the apparatus, and the care taken in the screening, etc., of the components can be seen on reference to these.

THE CALIBRATION AND CONSTRUCTION OF A STANDARD FREQUENCY METER

In 1923 the Marconi Company decided to improve their Laboratory Standard Wavemeter, and to this end certain experiments were carried out on the measurement of high frequencies and also on mechanical details for the instrument, which were finally embodied in the finished designs.

The following article deals briefly with the design and construction of the wavemeters finally adopted, together with an account of the method of calibration by alternator which is used for all accurate frequency measurements.

The development of the frequency measuring apparatus described below has been carried out by Messrs. T. D. Parkin and H. W. Prattley.

THE Marconi Company now uses as its standard wavemeters two instruments with ranges of approximately 0.8×10^3 to $2.7 \times 10^5 \sim$ in 12 ranges for one instrument; the other 2.5×10^5 to $7.1 \times 10^6 \sim$ in 8 ranges.

Description of Instruments.

The first of these two wavemeters consists of 3 inductances, 4 fixed air condensers, 1 variable Laboratory Standard Air Condenser, Valve Detector with batteries, Indicating Galvanometer and Reflecting Galvanometer, and busbars, the circuit being as shown in Fig. 1.

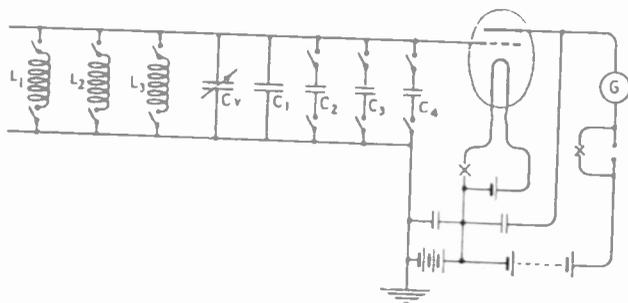


FIG. 1.

The inductances consist of 3 Porcelain Tubes wound with No. 20 Enamelled Copper Wire for a certain fraction of their length.

At each end of each tube is a divided brass band to one section of which the ends of the windings are soldered.

The Calibration and Construction of a Standard Frequency Meter.

The large tube has eight segments per band, the second six segments per band, and the third four per band.

Each segment is insulated from every other segment, the idea being to avoid a short circuited turn at each end of each inductance.

The detail is given in Fig. 2.

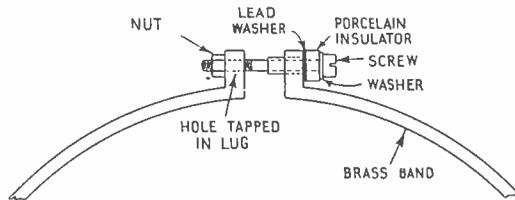


FIG. 2.

Each tube is mounted in a wood and glass octagonal case, and lies with its axis horizontal. The wire of the winding having been soldered to a small lug on one segment of the appropriate brass band, it passes unbroken to a terminal mounted on one side of the case.

The inductances are approximately 17,100, 1,910 and 203 mhs. respectively, and are connected to the fixed busbars by copper straps as required.

The variable condenser is a Standard Laboratory Air Condenser with a 0—180° scale and has a capacity of 0.000255 mfd. at 10° and 0.00396 mfd. at 170°, entirely metal screened, with screen and moving plates earthed.

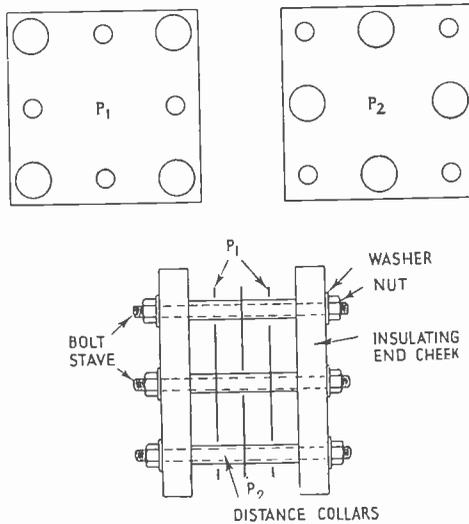


FIG. 3.

The Calibration and Construction of a Standard Frequency Meter.

The four fixed air condensers are built up on the Kelvin principle (Fig. 3) and consist of a number of Zinc plates, each held at 8 points and accurately spaced, the whole being held between two ebonite plates. The plates stand vertical and each condenser is enclosed in a sheet steel case.

Terminals are brought through the tops of the cases, the cases are all earthed, and when in use one set of plates is earthed. The first of these condensers is permanently connected in parallel with the variable condenser; the others are connected as required by removable busbars which are numbered in pairs, Left and Right, to ensure that the same pair of bars is always used when connecting in any particular condenser. It was found necessary entirely to remove the busbars from the unused condensers as errors could be detected if these were just disconnected from one end.

The approximate capacities of the fixed condensers are 0.001386 mfd., 0.003469 mfd., 0.00345 mfd. and 0.00344 mfd.

These give ranges as follows, between certain limits of the variable condenser, the limits not being the same for every range:—

Range	No. of Inductance	Fixed Condenser	Variable Condenser	Frequency Range (cycles)
1	No. 1	3	1	9,878—11,273
2	" 1	" 3	" 1	11,165—13,298
3	" 1	" 2	" 1	13,158—17,153
4	" 1	" 1	" 1	17,035—30,380
5	" 2	" 4	" 1	29,105—33,219
6	" 2	" 3	" 1	32,940—39,234
7	" 2	" 2	" 1	38,857—50,615
8	" 2	" 1	" 1	50,198—89,938
9	" 3	" 4	" 1	88,252—100,708
10	" 3	" 3	" 1	99,912—119,019
11	" 3	" 2	" 1	118,006—153,742
12	" 3	" 1	" 1	152,358—273,682

The curve shown in Fig. 4 shows the change in anode current in the standard circuit detector valve in Range 4 as this circuit is brought into tune with an oscillator of suitable constant frequency, and from this can be seen the limit of accuracy to which the standard circuit can be tuned.

It will be seen that by tuning the condenser to 0.1° a change of 8.8 cycles in 21,000 can be detected.

The valve detector circuit needs no comment being of the usual type with about 140 volts H.T. and suitable grid negative to ensure that no grid current flows under working conditions.

It might here be remarked that it took about 2 years for the condensers to settle to a final steady value.

The whole is mounted on a 6 legged rigid table bolted to the floor.

The smaller wavemeter is not very different to the large one, but it only has one fixed, and one variable air condenser, and 6 windings all on one tube, spaced, and fitted with the divided bands where necessary.

This wavemeter is entirely mounted on a heavy teak base which is completely covered with copper.

The H.T. battery and grid negative battery are contained in a cavity in the base, and on the lid of this cavity is mounted valve, galvanometer, switches and certain busbars. Heavy conductors come through the lid of this cavity from the H.T. battery and grid negative battery, so arranged that should the battery fail, it can be inspected and renewed without disturbing the lay-out of the circuit.

The variable condenser is again a screened Laboratory Standard Air Condenser with screen and moving plates earthed, and with a capacity of 0.000064 mfd. at 10° and 0.00051 mfd. at 170°.

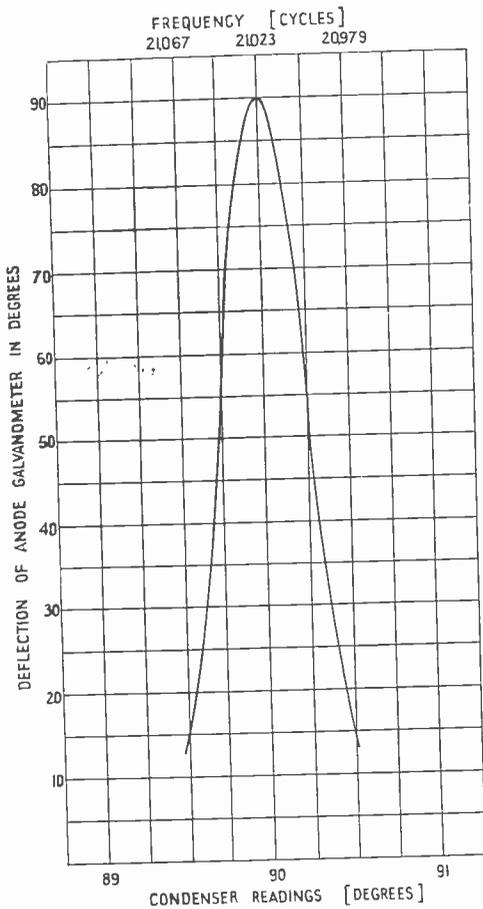


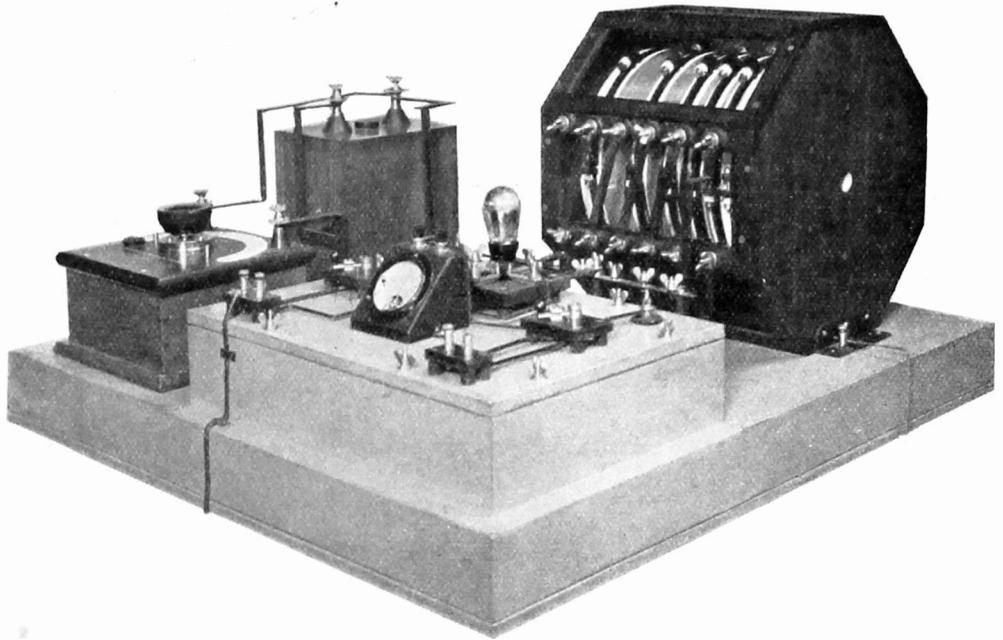
FIG. 4.

The fixed condenser is permanently connected in parallel with the variable one and consists of two heavy brass plates, between which are mounted 3 other plates of suitable size, and suitably separated. This condenser is on the Kelvin principle as before, and the outer plates are used as electrodes. The minimum amount of solid insulation is used and the whole condenser is enclosed in a copper lined heavy teak case. Terminals protrude through the top.

The inductances are wound on a former similar to the second one of the big wavemeter, and are 6 in number. Two of these are single turns of $\frac{1}{2}$ in. by $\frac{1}{8}$ in.

The Calibration and Construction of a Standard Frequency Meter.

copper; the other four are 3, 5, 13 and 22 turns respectively of 20 S.W.G. Enamelled Copper Wire. Each winding has two terminals and by strapping and connecting as required 8 ranges are secured.



Short Wave Wavemeter.

The ranges are :—

Range 1	..	..	253,378—397,878 cycles
.. 2	..	..	388,600—608,520 ..
.. 3	..	..	592,886—914,634 ..
.. 4	..	..	874,636—1,369,840 ..
.. 5	..	..	1,339,210—2,076,130 ..
.. 6	..	..	2,022,930—3,061,220 ..
.. 7	..	..	3,045,690—4,958,690 ..
.. 8	..	..	4,360,470—7,177,030 ..

A characteristic curve of Range 8 is given in Fig. 5, for a condenser reading of 90° , and it will be seen that mistuning by 0.1° gives rise to an error of 1,530 cycles in 5,349,500 which corresponds to an error of 1 in 3,500.

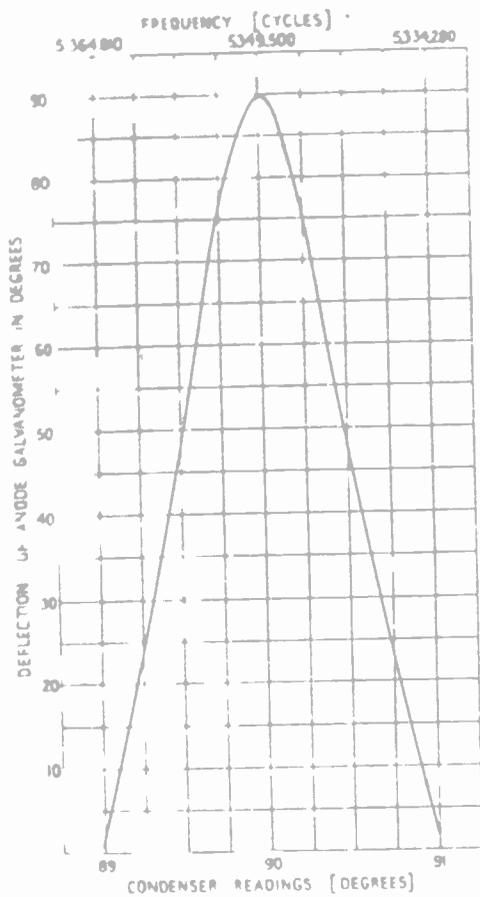


Fig. 5.

The tuning of the L.F. oscillator is then continued and the coupling again adjusted until after repeated tuning and adjustments a multiple of the L.F. oscillator frequency is in step with the H.F. oscillator and the L.F. signal is heard as a pure note at T , the telephone. If the frequency of the L.F. oscillator can now be measured, and multiplied by the correct harmonic, it will give the frequency of the H.F. oscillator. This is done as follows:

The L.F. oscillator is calibrated to a medium degree of accuracy in cycles per second. The alternator which is in another part of the building, removed from the measuring apparatus, is run up, and a small choke connected to the A.C. supply is presented to one or other of the transformers of the multi-stage Note Magnifier. This will give rise to a beat note between the received L.F. signal and the alternator, which will be heard in the telephone, and if strong enough will operate relay R_c .

Method of Calibration.

The calibration has been done by the aid of a steady running alternator as follows:

A H.F. oscillator, a L.F. oscillator, a detector circuit with a multiple note magnifier terminating in a relay circuit, two recorders, a standard clock, and the alternator have been installed.

The complete diagram of connections is as shown (Fig. 6).

The H.F. oscillator is started and the detector and wavemeter tuned to it, by observing the galvanometers, the grid of the detector valve being slid well back to negative.

The couplings must be of such looseness that when tuning any one of these 3 circuits, no detuning of the others occur. This necessitates the use of a powerful H.F. oscillator far removed from the other circuits.

The L.F. oscillator is then started and is so tuned that one of its harmonics is approaching the frequency of the H.F. oscillator. The coupling K is adjusted to a

minimum working degree.

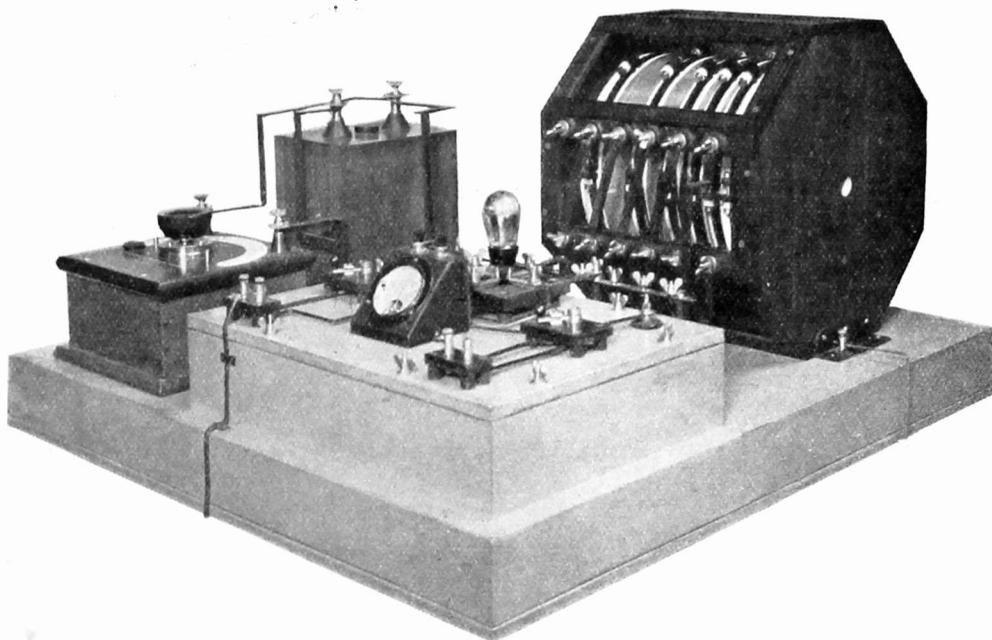
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The Calibration and Construction of a Standard Frequency Meter.

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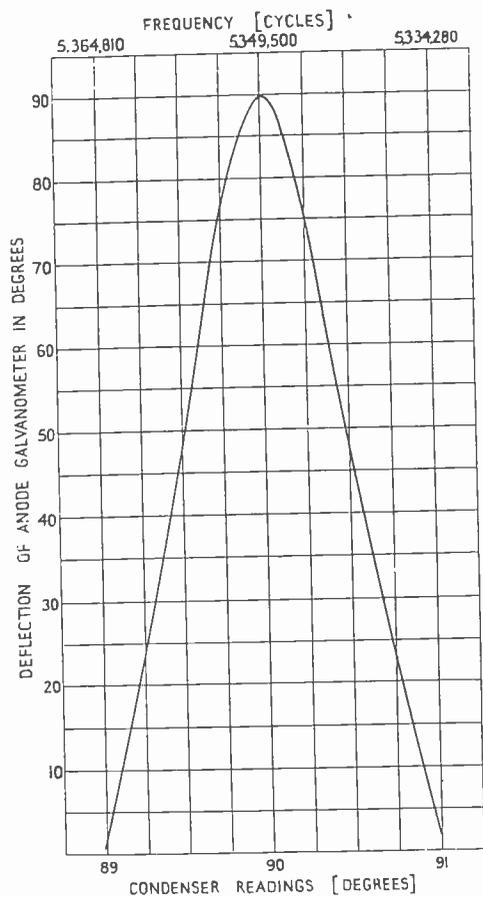


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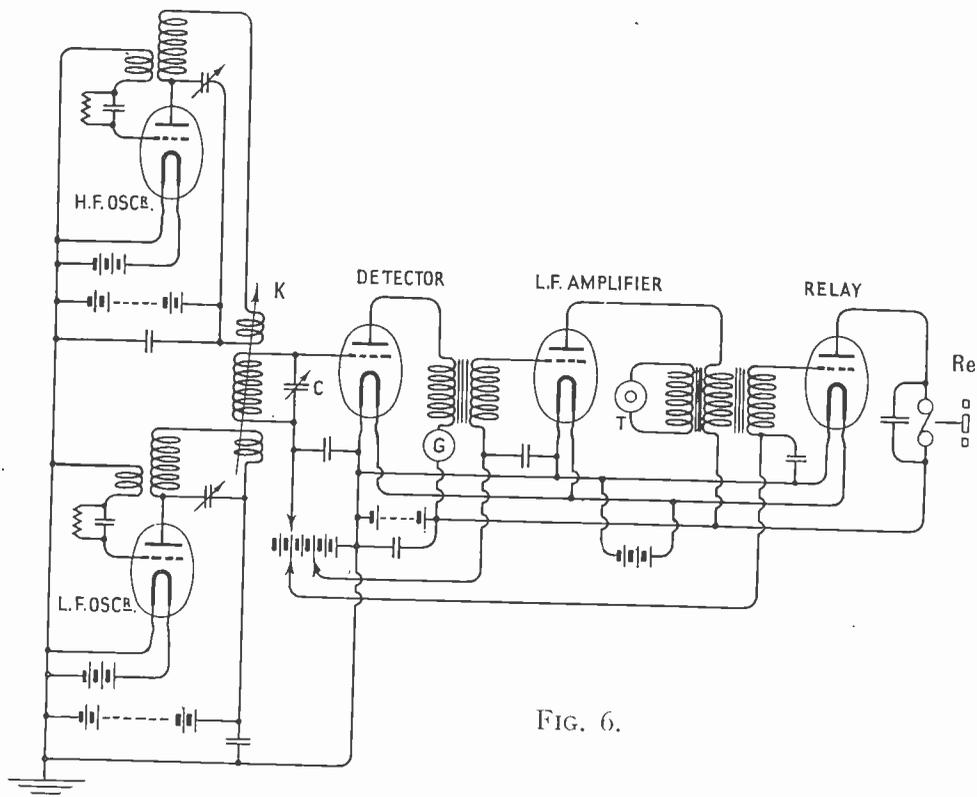


FIG. 6.

It is imperative to know if the alternator frequency is higher or lower than that of the L.F. oscillator. A rule is made of running the alternator a few cycles slower

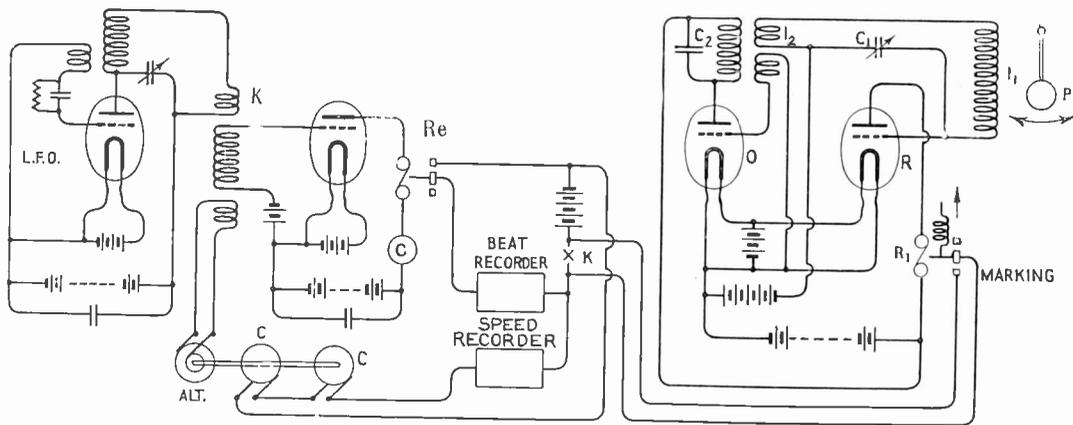
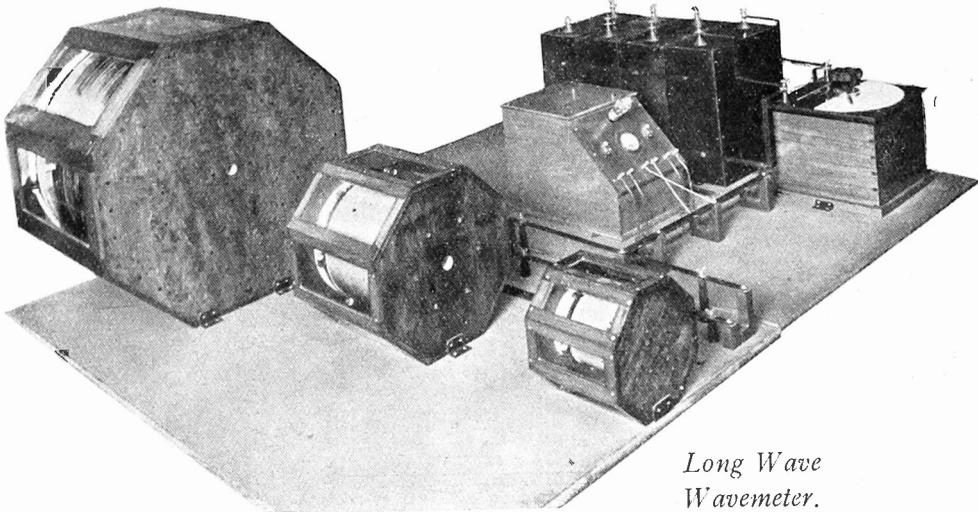


FIG. 7.

than the oscillator. Relay R_e , being in operation the beats can be recorded over a length of time on the slow beat recorder (Fig. 7).

The Calibration and Construction of a Standard Frequency Meter.

The oscillator Frequency is Machine Frequency plus Beat Frequency per sec.
The machine frequency is found in the following manner :



On the shaft of the alternator are two commutators geared $10/1$ (Fig. 8). The high speed one which is at shaft speed has $9/10$ of its periphery insulated and $1/10$ conducting. The low speed has $1/10$ insulated and $9/10$ conducting. Each is provided with 2 brushes which are connected as shown in Fig. 8. A phasing arrangement between the two commutators is fitted.

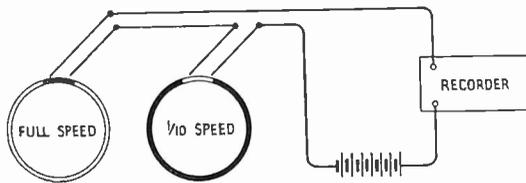


FIG. 8.

The machine has 60 pairs of poles, therefore R.P.M. are equal to cycles per second.

If the machine is run with the two commutators, a battery and a recorder in series, the recorder tape will be a series of dots with every tenth one missing as shown in Fig. 9.

This missing occurs when the insulated portion of the slow speed commutator passes under its pair of brushes when the conducting portion of the high speed commutator passes under its pair of brushes. This is a device for facilitating

counting. Dots can be counted in tens and end ones added. The complete number so found, divided by time of run in minutes, is cycles per second.



FIG. 9.

The timing of a run presented great difficulty. It was found that the eye was not automatic enough to enable accurate switching to be done. A device to improve timing was therefore built up. This consists of an oscillating valve and a detector valve. The filaments of these together with a resistance are in series across the station battery. H.T. is also supplied by the same battery. From the oscillator a single turn coupling is taken and connected in series with a small coil which is placed behind the pendulum of the standard clock, to be just overshadowed by the pendulum

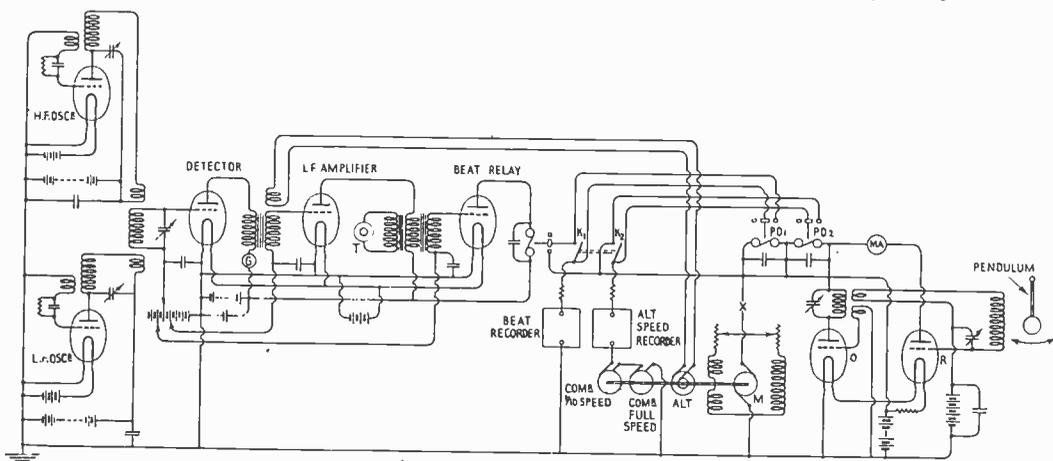


FIG. 10.

when it is at its full swing (Figs. 7 and 10). A tuning condenser is connected across the extremities of the coupling and choke coil which are as stated in series. The pendulum of the clock is of beech wood with a brass bob and makes one complete swing in two seconds. The tuned circuit is connected to grid and filament of the detector valve with suitable grid negative, and is so arranged that it is brought into tune with the oscillator when the pendulum is at full travel. Anode current then passes and relays PO_1 and PO_2 are operated for a short time (Fig. 10).

Across the contacts of PO_1 and PO_2 are connected the switches K_1 and K_2 respectively. These switches are operated by one handle and have micrometer contacts so that both close and open together. On account of the swing of the pendulum PO_1 and PO_2 are operated every two seconds, and if the alternator is running with circuits and recorders switches out, a record will appear on the tapes at 2 sec. intervals (Fig. 11).



FIG. 11.

If now the switches K_1 and K_2 are closed the two second break is obliterated and the recorders show the continuous record of machine dots in groups of 10, and a record of the slow beats between alternator and L.F. oscillator.

Everything being adjusted as described the observer waits for the second hand of the clock to arrive at a marked place on the dial. At this point PO_1 and PO_2 close by means of the pendulum valve circuit and the switches are then closed by hand. A run of a suitable length of time is now made and as the second hand again approaches the marked point on the clock dial, after the proper period of time, the switches K_1 and K_2 are opened, immediately before the completion of the time, and on the actual completion of the time, the clock valve relay again operates closing the relays, PO_1 , PO_2 and causing the recorders to operate.

This gives a tape as shown (Fig. 12) :-

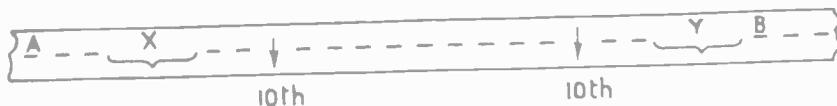


FIG. 12.

The actual run is from the first dot A to the dot B. It will be seen that at X and Y blanks occur. These correspond to the lag in closing and the lead in opening the switches K_1 and K_2 by hand, but as the tape record is divided in tens, and as the tape speed is constant over short intervals of time, these missing dots can be filled in without any fear of error.

The machine speed and beat frequency is now known from which is derived L.F. oscillator frequency.

Selection of Harmonics.

In the experiments both the high and low frequency oscillators have been calibrated. As the first wavelength measured was of the order of 10,000 cycles, the L and C values of the various circuits did not permit of a great error arising. The machine running at approximately 2,500 r.p.m. the H.F. was the fourth harmonic of the alternator frequency. This harmonic was multiplied by the L.F., which gave the H.F. value. From this steady progression to higher frequencies in small steps has been made many readings being taken on each point, and curves being drawn as the results were obtained, the harmonic increasing with the higher frequency. This method left no chance of error, for had the wrong harmonic been taken as the multiplier the curve would have shown a very sharp rise or fall not in accordance with the standard condenser calibration.

Above 300,000 cycles it has been necessary to instal a higher frequency oscillator. The method is substantially as before, but in this case having set up the higher frequency oscillator, the medium frequency oscillator is started and tuned to zero beat, with the higher frequency oscillator, then the L.F. oscillator is started, and the adjustments are made as before, checking the medium frequency oscillator as in the case of lower frequencies.

Starting off from a known point which had been calibrated on the medium frequency wavemeter careful measurements in small steps were made to the higher frequencies.

The frequency meters described have a band of from 9,878~ to 7,177,030~ but it is often necessary to measure frequencies of a much higher order.

To do this the system is again extended and a very high frequency oscillator is set up and caused to interfere with, and then tuned to zero beat with an harmonic of the next lower frequency oscillator, after which the method is as described for measuring frequencies up to the limit of the calibrated instrument.

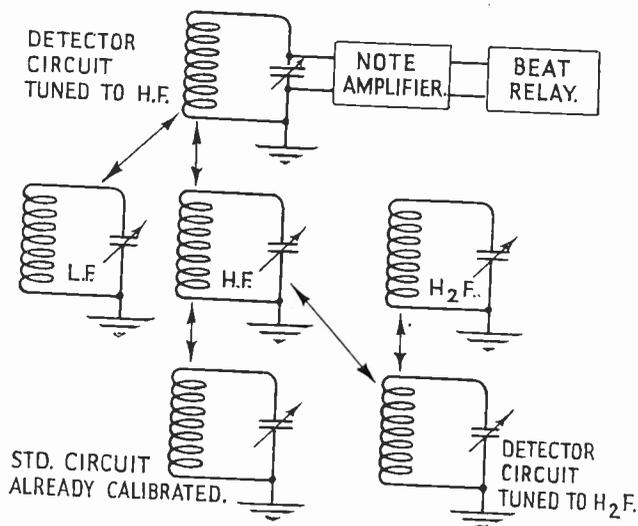


FIG. 13.

In conclusion the following remarks may be made.

The clock is of good quality, and is checked at least twice daily by means of time signals and a curve drawn. This gives a correction to be applied for each measurement made.

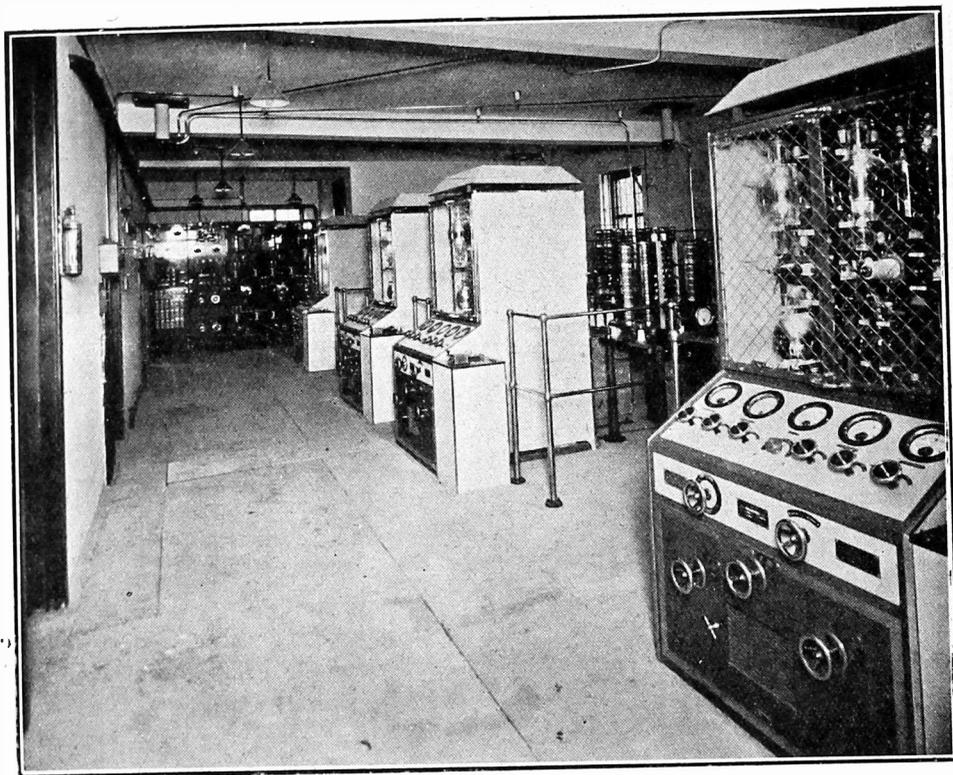
The scales of the instrument can be read to 0.1°.

In the case of a very definite measurement being required, *i.e.*, station jamming, the wavemeter reading is regarded as of secondary importance, and the station is measured by the fundamental method.

T. D. PARKIN.

MARCONI NEWS AND NOTES

AIR ROUTE TO INDIA THE WIRELESS ORGANISATION



London Air Port. Transmitter Hall with four transmitters designed and installed for the Air Ministry by Marconi's Wireless Telegraph Company, Ltd.

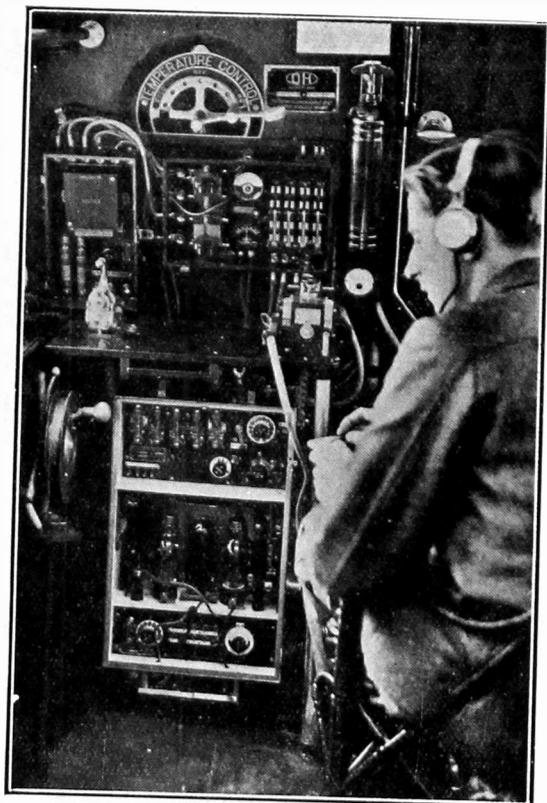
THE wireless organisation for the air mail service to India, which was inaugurated on March 30th, forms a complete chain so that the aircraft engaged are in touch with aerodrome ground stations throughout the 4,700 air miles of the journey from London to Karachi.

All the aircraft are equipped with Marconi wireless apparatus of the latest type, and an intercommunicating chain of ground stations has been arranged.

The first section of the route is the London-Basle flight, on which the present wireless organisation for Continental aviation will be employed. This consists of

the powerful Marconi aerodrome station at Croydon, French stations at Le Bourget and other intermediate places on the route, and the Marconi station at Basle. The

machines operating this section of the route—Armstrong Whitworth Argosies—are fitted with Marconi sets of 150 watts power, of the well known Type A.D.6, adapted for communication over distances of 200 to 300 miles either by telephony or telegraphy.



Marconi A.D. 6 Aircraft set fitted in Imperial Airways passenger machine.

capable of communicating with Malta, Alexandria (Aboukir) and other stations concerned with the service.

At Alexandria a change is made to aeroplane again to continue the service over the third and final section of the route, through Basrah and over the Persian Gulf to Karachi. Part of this section has already been in operation for some time, employing De Havilland aircraft fitted with Marconi A.D.6 apparatus and communicating with R.A.F. stations and a $\frac{1}{2}$ kw. station at Rutbah Wells, which was supplied by the Marconi Company to the Iraq Posts and Telegraphs Department. During the flight from Basrah to Karachi, the machines will be in touch with two Marconi stations in Persia, at Chabar and Bunda Abbas. Persian operators for these stations have been trained at the Marconi Company's Works at Chelmsford,

A Powerful Aerodrome Station.

The terminal wireless station at Karachi is one of the most powerful aerodrome stations installed at any air port, consisting of a 6 kw. Marconi transmitter with direction finder receiving apparatus.

Many features of the Marconi apparatus for this service have been specially designed to meet the conditions existing on this new Empire route. The constant-speed windmill generator which provides power for the wireless installation will also supply current for the internal and external lighting of the aircraft. In the unlikely event of a forced landing being necessary the same generator can be used to supply emergency power to the transmitter either by the use of the battery normally used for lighting or, if it is required to work for long periods, by means of a special coupling arrangement to the small petrol engine used for starting the main engines of the aircraft. Thus, even if a machine were forced to land in the solitudes of the desert country which is to be found along the route, wireless communication could be established with the nearest ground station and any required assistance could be obtained.

The Air Ministry and Imperial Airways, Ltd., with the co-operation of the Marconi Company, have given very careful consideration to the wireless requirements of this first long distance Empire aviation route, and the comprehensive system of communications provided both for the ground stations and in the aeroplanes will render the England-India air route among the safest and most efficient in the world.

New High Power Broadcasting Transmitter for Sweden.

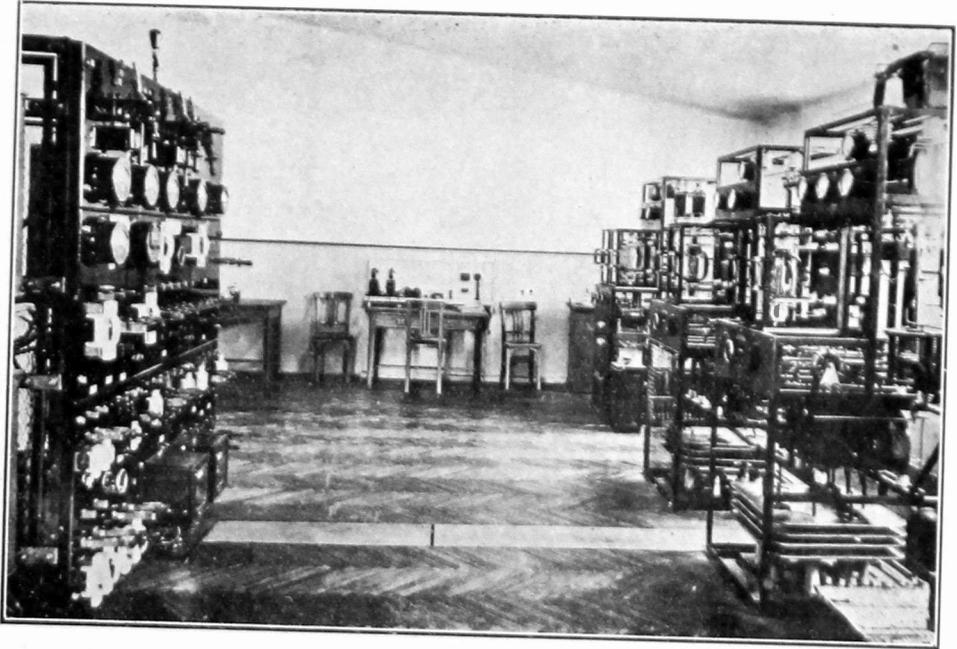
The Swedish Government has placed an order with the Marconi Company for the supply of a 60 kw. aerial energy transmitter for installation at Stockholm.

This contract was obtained by the Marconi Company in the face of the keenest competition, a success which is a tribute to the excellent design and performance of British broadcasting transmitters.

The new Swedish broadcasting station will be effective over a very large area. It will be operated on the low-power modulation system, with deep and distortionless modulation, and will be worked direct off a three-phase public electric power supply.

Marconi Broadcasting installations are now operating in over 20 countries outside Great Britain.

Marconi Broadcasting Transmitter in Yugo Slavia.



Marconi 9 kw. Broadcasting Transmitter at Belgrade.

A Marconi 9 kw. broadcasting transmitter has been installed at Belgrade for the Yugo Slavian broadcasting authority.

The official inauguration took place on Sunday, March 24th, in the presence of a representative of the King of the Serbs, Croats, and Slovenes, Members of the Cabinet and other high Government officials. The station was reported to be an unqualified success owing to the high efficiency of the transmitter. It gave very satisfactory performances during its tests, and a Swiss observer describing his reception of this station in *World Radio* says:—

“Modulation is perfect and there is very little fading. I think I can safely promise that this newcomer to the Continental ether will be easily heard in England at good loudspeaker strength. Speaking from a mid-European point of view, Belgrade—which seems well clear of all the stations and is neither interfered with, nor itself causes any interference—is a very welcome addition, and I think we can now look forward to some enjoyable programmes from this historic city.”

An English correspondent to “Radio Belgrade” reports that station “just as distinct as our own station in Liverpool, and clearer and louder than any other Continental station.”

This 9 kw. installation, Type Q, is one of the smaller Marconi broadcasting stations delivering 2 kw. to the aerial. Before acceptance it had to pass extremely onerous reception test conditions.