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AN APPLICATION OF THE CIRCLE DIAGRAM TO THE DESIGN OF ATTENUATION AND PHASE EQUALISERS

(PART II.)

In the last number of THE MARCONI REVIEW, *the first part of an article dealing with a new construction of equalising and correcting networks was given.*

This article is concluded in the following pages.

IN cases where the shape of any of the attenuation curves is not suitable to meet any specific requirements the use of more complex circuits is required and there are two methods that can be used. The first is that of multiplying the correction effects. In Fig. 10 the full bold lines indicate a circuit of the type of 1A. Now as a circuit of this type behaves as a resistance at all frequencies, it is clear that the two resistances in the circuit itself may one or both be replaced by similar circuits, and again the resistances in these circuits may be replaced by further circuits and the process may be carried on indefinitely. In Fig. 10 the main circuit shown in thick lines has had its resistances replaced by the circuits shown in thick dotted lines, and the resistances in the latter circuits have in turn been replaced by the circuits shown in thin lines, and finally the resistances of the latter have been replaced by the circuits shown in thin dotted lines leaving the circuit finally bounded by a chain of sixteen resistances, each equal in value to the hypothetical resistances they have replaced, or to $\sqrt{\frac{L}{C}}$. For simplicity in the case being considered the same values of L and C have been chosen throughout, though this need not have been so, a different quadrantal frequency could have been chosen for each circuit so long as the ratio $\sqrt{\frac{L}{C}}$ was made equal to the resistance R, hypothetical in every case but the last set of circuits. Now it is interesting to apply the circle diagram to analyse this case and to assist in doing this the various junction points in the circuit have been numbered and it will be found that the numbers correspond with these on the circle diagrams for the case Figs. 11 and 12. The lines on the two diagrams have been made to correspond also, i.e., thick lines to the circuit in thick lines, etc. Two cases have been drawn out, one for the quadrantal frequency, and one for half the quadrantal frequency.

The simplest way to consider the diagrams will be to follow them through systematically piece by piece. Thus considering Fig. 11 (drawn for the quadrantal frequency) in conjunction with Fig. 10, the vector 0—8 defines the potential between the points 0 and 8 where 0—16 represents the E.M.F. applied right across the circuit. Similarly to find the potential across the inductance in the next row in Fig. 10 it is necessary to apply to the vector 0—8 the same construction as was applied to 0—16 when 0—8 was obtained, and the result of this operation is the vector 0—4. Similarly from 0—4, 0—2 is derived, and finally from 0—2, 0—1. As the same construction is applied each time the result is that the original vector is divided by the same factor each time the process is applied. In the case considered at the quadrantal

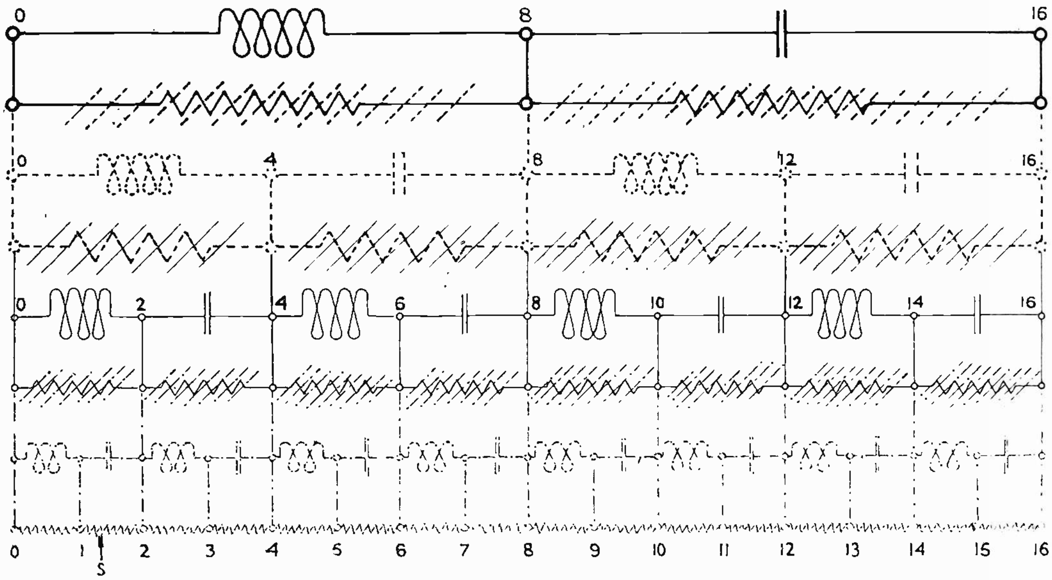


FIG. 10.

frequency and for the circuit arranged as in Fig. 10, with one tapping point remaining at 0, the other being progressively tapped across the first inductance in each row, each time the tap is moved down one row the vector potential is divided by $\sqrt{2}$ and the angle is swung through 45°, as is shown in Fig. 11. In the other case considered which is shown in Fig. 12, it will be seen that the vector is divided by 2 at each step and swung through 60°. The 0 per cent. curve 0—(1)—S on Fig. 4 may be made as explained above, correctly to represent the attenuation at point 8 for any frequency, and the similar curve on Fig. 6 the phase angle. Thus in the case considered where the quadrantal frequencies are all the same, if the ordinates of the frequency and phase angle curves are multiplied by two they represent the potential 0—4, when multiplied by three the potential 0—2, and when multiplied by four that of 0—1. In cases where the quadrantal frequencies of each circuit were different it would be necessary to obtain the correct curve corresponding to the quadrantal frequency of the first section, add to it that corresponding to the quadrantal frequency of the next, and so by a series of successive additions obtain the final curve. By using progressively changing quadrantal frequencies at each stage it is possible to expand the range of frequencies over which the attenuation take place.

Remembering that the diagrams Figs. 11 and 12 may for the particular frequencies for which they are drawn, be regarded as a kind of potential map in which the lines joining any two points vectorially represent the potential between them, it will be seen that by a process of step by step addition, or in the cases where the

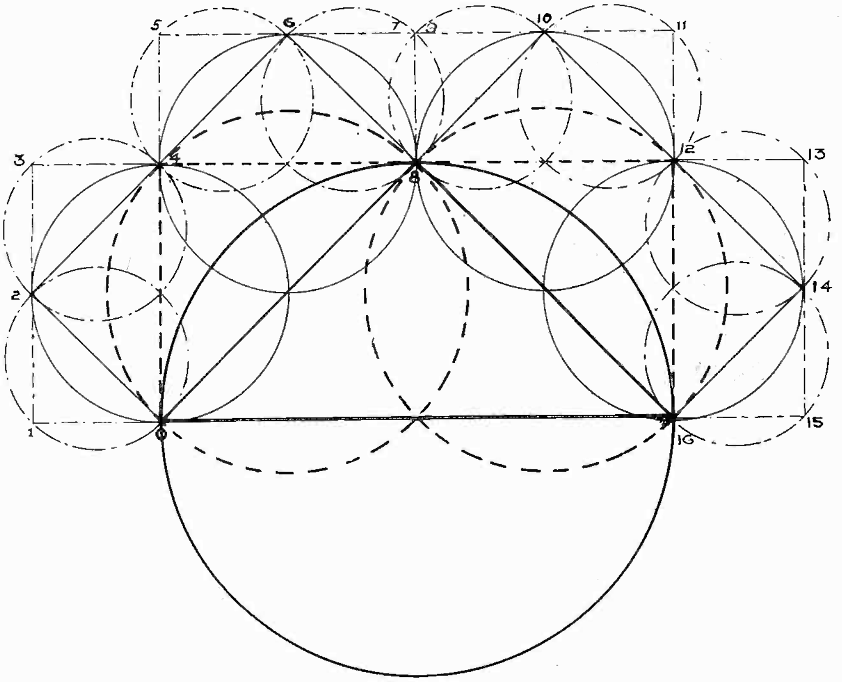


FIG. 11.

same quadrantal frequency is used—multiplication and addition—the potential between any two points at any frequency may be found. To take a specific example, using a simple case for ease of illustration, what is the curve expressing the potential 0—(1)—S at different frequencies, when S is placed 20 per cent. along the resistance 1—2? It is clear that the relative potential of 0—(1)—S to 0—2 is expressed by the 20 per cent. curve 0—(1)—S of Fig. 4. Now the potential 0—2 may be obtained as explained from the 0 per cent. curve by multiplying the ordinates, expressing attenuation in decibels, by three. Therefore the complete process is multiply 0 per cent. curve by three and add 20 per cent. curve 0—(1)—(S). In practical cases where the circuits are used to produce a certain required correction curve, and a multi-stage circuit is found to be necessary, it is usually possible to simplify them considerably and still allow a wide margin of adjustment. For example a correction *between* 3 and 4 times the 0 per cent. correction 0—(1)—S Fig. 4 might be required, would be provided by the arrangement 0—(1)—S, of Fig. 10, where S is a movable tapping point or slider, to provide a ready means of adjustment. Now it is clear that to meet these specific requirements the circuit could be simplified to the form shown in Fig. 13.

It is clear that arrangements of circuits may be devised, using the principles enunciated, to meet a large number of correction requirements, but conditions may

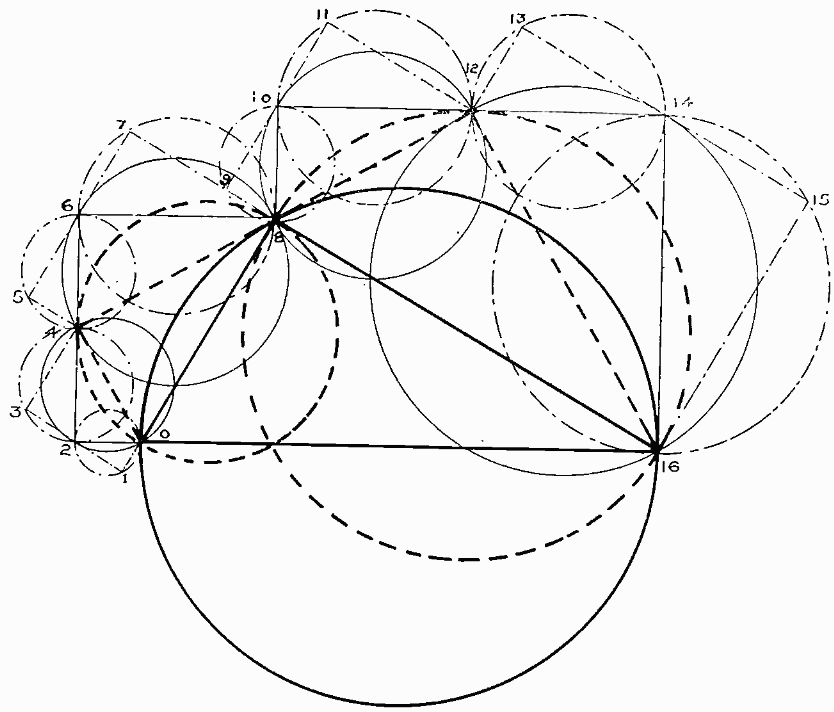


FIG. 12.

arise in which it is necessary to produce correction effects over a relatively narrow frequency spectrum and it is for these conditions that the resonant arm circuits find application, and the theory of these circuits will now be developed. The principles involved are very simple and are based on the fact that below its resonant frequency a series resonant circuit behaves as a condenser, and a parallel resonant circuit as an inductance, and that at any *actual* frequency below resonance an *equivalent* frequency may be derived, this equivalent frequency being the same for both the series and parallel cases, from which and the *capacity* of the series resonant circuit and the *inductance* of the parallel resonant circuit may be worked out the impedance of these circuits by merely replacing the equivalent frequency for the actual frequency, in the usual expression for the impedance of the capacity and inductance. Similarly, above the resonant frequency the series arm may be treated as an inductance of the same value as the inductance of the circuit but behaving at another equivalent frequency and this same equivalent frequency will define the impedance of the parallel resonant circuit by considering it as acting on the condenser of that circuit.

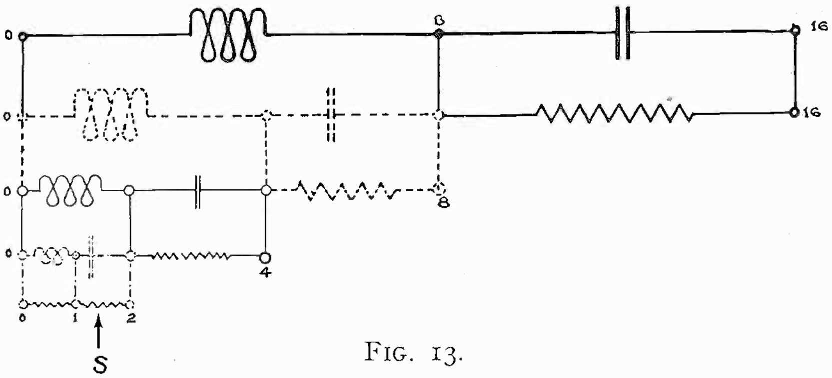


FIG. 13.

In order to define the angular velocities corresponding to the various frequencies clearly let us use the following symbols :—

w_o the angular velocity at *resonance*.
w an *actual* angular velocity below resonance.
w' the corresponding *equivalent* velocity.
w_q an *actual* quadrantal velocity below resonance.
w_q' the *equivalent* quadrantal velocity from which this is derived,

and similarly

w_1 an *actual* velocity above the resonant frequency.
w_1' its *equivalent* velocity.
w_{1_q} an *actual* velocity at the quadrantal frequency above resonance.
w_{1_q}' the *equivalent* quadrantal velocity from which this is derived.

That is, the suffix $_o$ is used for resonance, the other suffixes being $'$ for equivalent velocities, $_q$ for quadrantal velocities, and $_1$ for velocities above resonance, and these latter suffixes may be combined as required.

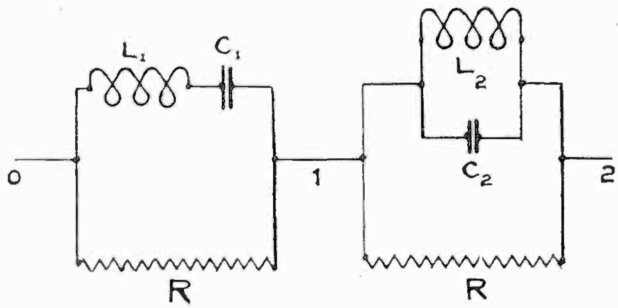
Now consider Fig. 14A which corresponds to Fig. 1A, in which the circuits L_1C_1 and L_2C_2 are resonant to the same frequency. Now below this resonant frequency L_1C_1 behaves as a condenser acting at an equivalent frequency w', its impedance being $\frac{j}{w'C_1}$, whilst the circuit L_2C_2 acts as an inductance the impedance of which is defined by $jw'L_2$ where

$$w' = \frac{ww_o^2}{w_o^2 - w^2}$$

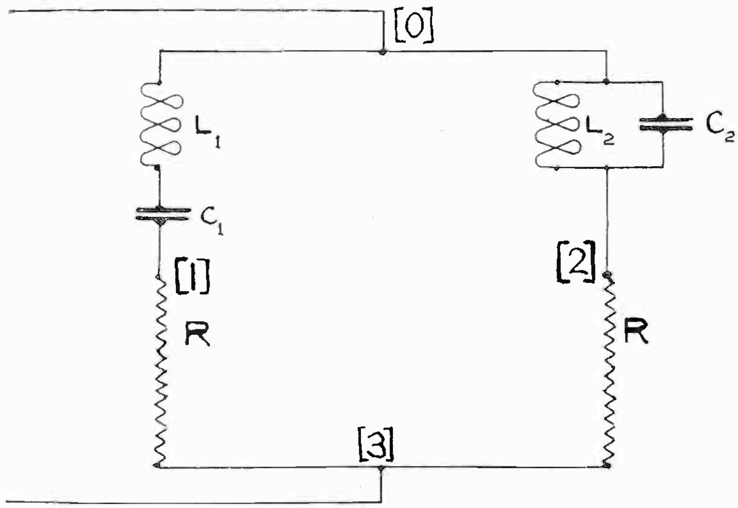
Again above the resonant frequency the circuits L_1C_1 and L_2C_2 behave as an inductance L_1 and a condenser C_2 respectively, both acted upon by an equivalent frequency w_1' which is derived from the actual frequency w_1 by the relation

$$w_1' = \frac{w_1^2 - w_o^2}{w_1}$$

Therefore in the first case (below the resonant frequency) if $\sqrt{\frac{L_2}{C_1}}$ and the second case (above the resonant frequency) $\sqrt{\frac{L_1}{C_2}}$ are each made equal to the resistance R, constant impedance conditions will be realised. It will be found that if the circuits



(A)



(B)

FIG. 14.

are both resonant at the same frequency, or $\sqrt{L_1C_1}$ equals $\sqrt{L_2C_2}$, that $\sqrt{\frac{L_2}{C_1}}$ then equals $\sqrt{\frac{L_1}{C_2}}$ and constant impedance conditions can be met at all frequencies below or above resonance. At resonance it is clear L_1C_1 will be zero impedance, L_2C_2 infinite, and the net result will be that the over-all impedance will still be equal to R.

It is obvious that there are two quadrantal frequencies, one below and the other above the resonant frequency, the former being defined by the relation that the equivalent quadrantal frequency w_q' equals $\sqrt{\dfrac{1}{L_2C_1}}$ and in the latter case

$$w_{1_q}' = \sqrt{\frac{1}{L_1C_2}}.$$

The circle of Fig. 15 is the locus of point 1 in Fig. 14A. The suffixes used are to be interpreted the same way as those applied to the angular velocities. The fundamental conception from the point of view of the circle diagram is the equivalent frequency in each case: the actual frequencies are shown in brackets. It will be seen that at zero frequency the L_1C_1 branch is open circuit and the L_2C_2 short circuit so the full potential is across 0--1, the locus point, therefore, as the frequency is

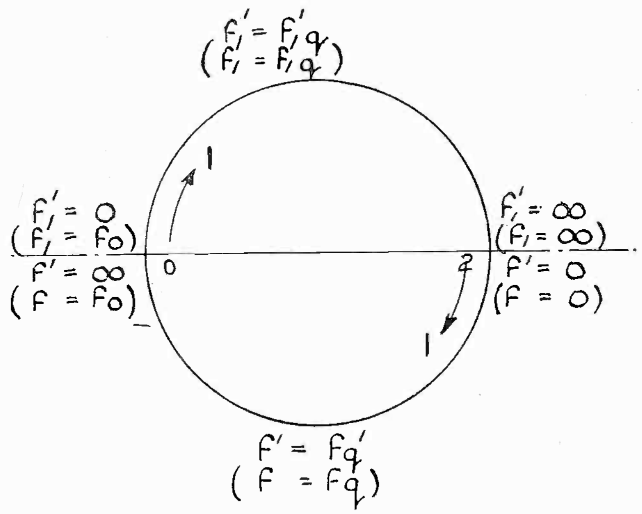


FIG. 15.

raised from zero, starts from 2 moves round the bottom semi-circle anti-clockwise through the first equivalent quadrantal frequency to the origin which is reached when the equivalent frequency is infinity the actual frequency then being the resonant one. As the frequency is raised from resonance, which is an equivalent frequency of zero for the conditions applying above resonance, the locus point sweeps out the top semi-circle through the second equivalent quadrantal frequency back to point 2 when both equivalent and actual frequencies become infinite. It is quite easy to apply the curves to meet any given set of conditions including those involving tapping positions on the resistances and in general it will be found that if one curve of the group represents conditions below the resonant frequency the companion and symmetrical curve to it sloping in the other direction will represent conditions above resonance.

Considering the two quadrantal frequencies it is quite clear that they are interrelated, and it is easy to show that they are logarithmically symmetrical to the

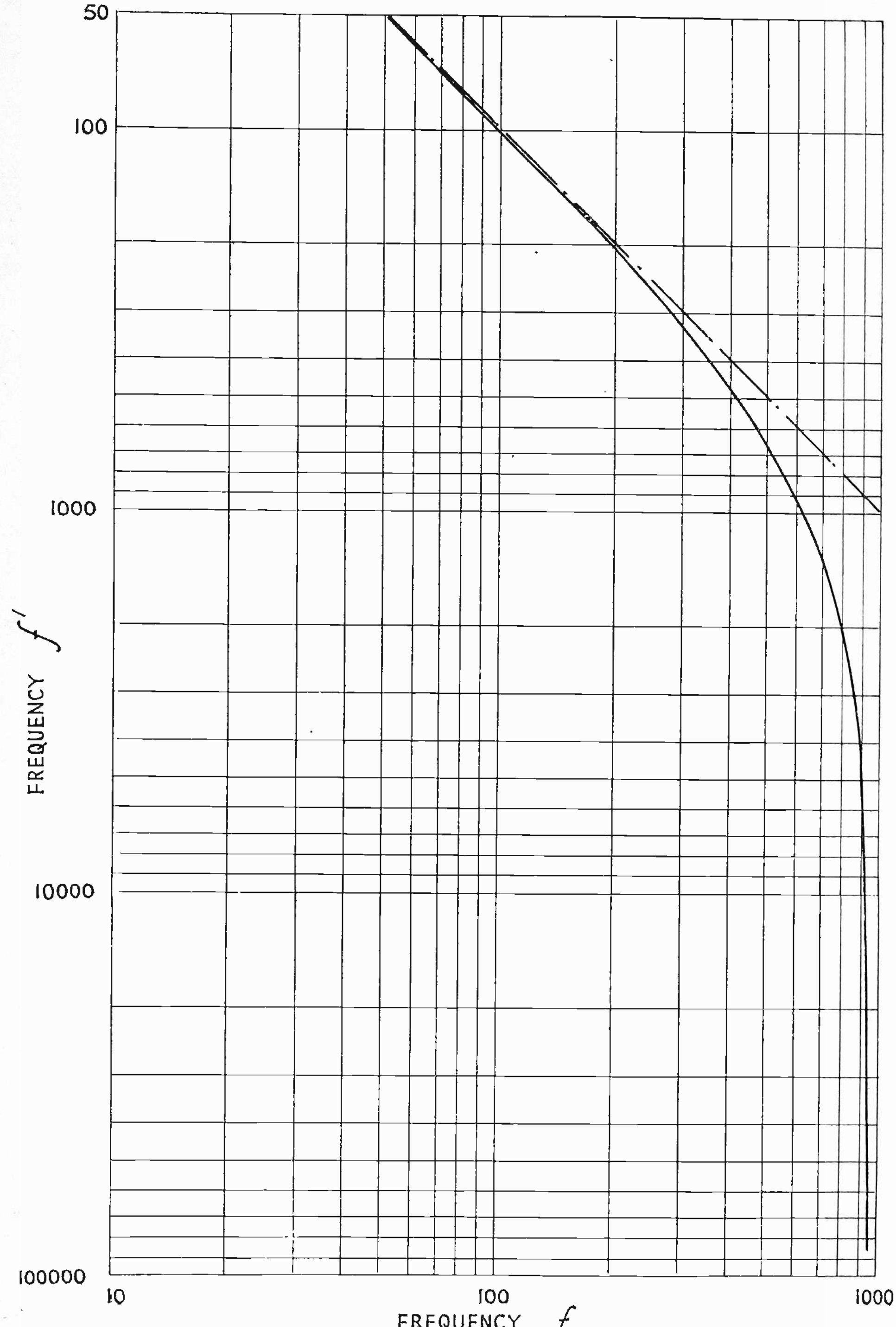


FIG. 16 (A).

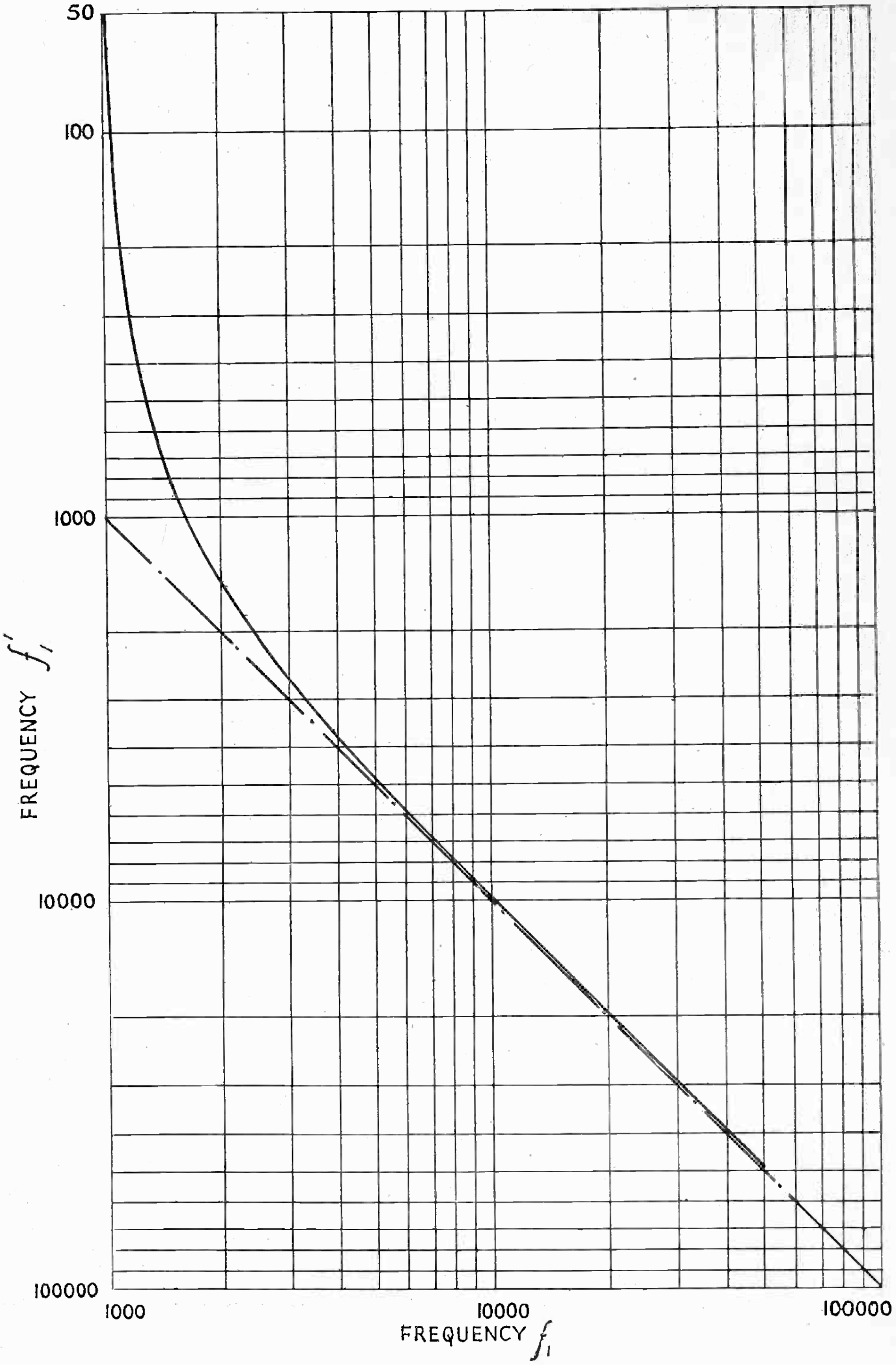

50
100
1000
10000
100000
FREQUENCY f_1'
1000
10000
100000
FREQUENCY f_1

FIG 16 (B).

resonant frequency. Now, remembering that the ratio of L_1/C_2 and L_2/C_1 are fixed by the resistance R, and that the product L_1C_1 must equal L_2C_2 and is fixed by the resonant frequency, the ratio of L_1 to C_1 can still be altered, any alteration involving an opposite alteration in the ratio of L_2 to C_2, and a little consideration will show that big ratios of L_1 to C_1 accompanied by small ratios of L_2 to C_2, move the actual quadrantal frequencies relatively nearer the resonant frequency, whereas small ratios of L_1 to C_1 with large ratios of L_2 to C_2 make these frequencies remote from the resonant frequencies. Alteration of these ratios to suit the conditions required thus afford a means of altering the frequency spectrum in which the effects are required to become operative.

In many cases where the resonant arm correction is used the resonant frequency is put outside the correction range so that only one group of curves comes into action. In plotting the resonant arm curves use has to be made of a curve defining the actual frequencies in terms of the equivalent ones, as the group of curves Figs. 4 to 9 is in terms of equivalent frequencies when applied to resonant arms. Such a curve is shown in Figs. 16A and 16B, 16A giving the equivalent frequency f' in terms of the actual frequency f_1 for frequencies below resonance, whilst 16B shows the relation of f_1' to f_1, the equivalent to actual frequency above resonance. In both cases the resonant frequency is 1,000, but as the scales are logarithmic the curves can be made to apply to other resonant frequencies by the following construction, which applies to both cases. Upon the diagram mark a hypothetical point f' or f_1' as ordinate, and $f = f_0$ as abscissa. Through this point draw a vertical line and a 45° degree line parallel to the dotted asymptote line to which the curves tend at frequencies remote from resonance. Now on tracing paper, trace out the curves from 16A or 16B and the 45° asymptote line and the vertical axis at 1,000 cycles, and slide this curve over the curve over 16A or 16B until the asymptote ordinate axis coincide with the ones marked for the new resonant frequency. The required frequencies can then be read directly from the traced curve using the squares and scales of the curve beneath.

It will be found that the nearer the quadrantal frequencies are placed to the resonant frequency, the more care will be required to be taken to keep coil and condenser losses down in order to make practical results accord with theoretical.

Referring to Fig. 14B, which is the counterpart of Fig. 1B, it will be clear that the outer circles of Fig. 2 can be made to express the relative potential conditions, and that the vectors [2]—[1] and [1]—[2] sweep right round the outer circle, or through 360° as the frequency is changed from zero, through resonance, to infinity.

Combinations including resonant arm circuits designed in the above manner may be treated in multiple in an exactly similar way to the basic circuits, and may have if required different resonant and quadrantal frequencies for each sub-circuit.

N. M. Rust.

WIRELESS TELEPHONE INSTALLATION ON THE "MONARCH OF BERMUDA"

The new liner "Monarch of Bermuda," owned by Messrs. Furness Withy & Co., which was built by Messrs. Armstrong Vickers at their naval yard, Newcastle-on-Tyne, left England on the 14*th November,* 1931, *for New York to take up her service on the New-York-Bermuda run.*

The radio telephone installation on this ship was carried out by the Marconi Co., and is briefly described in the following article.

THE Transmitter installed on board the "Monarch of Bermuda" is the Marconi Type S3B, a full description of which has been given in THE MARCONI REVIEW, No. 28. For the purpose of this article, however, we shall briefly summarise the main points of this transmitter below.

The Receiver is the Marconi Type RC45 which is similar to that installed on the "Empress of Britain" and described in THE MARCONI REVIEW, No. 32.

In the case of the "Monarch of Bermuda" 2 wire working is not employed, and in place of telephones being installed throughout the ship, a single telephone booth is erected near the purser's office where all subscribers' calls are connected.

Immediately after leaving England a communication was established with America and an excellent commercial circuit has been maintained.

The Transmitter.

The transmitter is capable of working on any wavelength between 20 and 120 metres, and is also provided for crystal control on 4 spot waves of 71·8, 71·18, 33·9 and 34·94, these 4 crystal wavelengths being those used by the ship on the Bermuda run. The power of the transmitter is rated 160—180 watts to the aerial for telephony, and 300 watts on continuous wave transmission.

A photograph of the Transmitter is shown in Fig. 1 and consists of a master oscillator with crystal control on 4 spot waves as has been mentioned above, master oscillator amplifier and 2 stages of power amplification shown as No. 2 and No. 1 magnifier in the schematic diagram given in Fig. 2. The standard type S3B transmitter has been suitably modified to include a carrier suppressor unit which cuts off the carrier of the transmitter when the subscriber ceases to speak and is rendered necessary by the fact that the transmitter is in close proximity to the receiver. The master oscillator box is situated on the right hand side of the transmitter and, together with the 4 spot crystal frequency circuits, is enclosed in a metal screened box and heated by heater lamps off the main D.C. supply. The temperature of the interior of the box is maintained constant by means of a thermostat at 140° F.

The use of this thermostatically controlled master oscillator ensures that the frequency of the telephone carrier is kept constant when modulating, thus facilitating transmission and avoiding any distortion which may arise due to carrier wobble when working on short waves.

Any one of the 4 spot crystal waves can be selected by a simple change over switch on the master oscillator box.

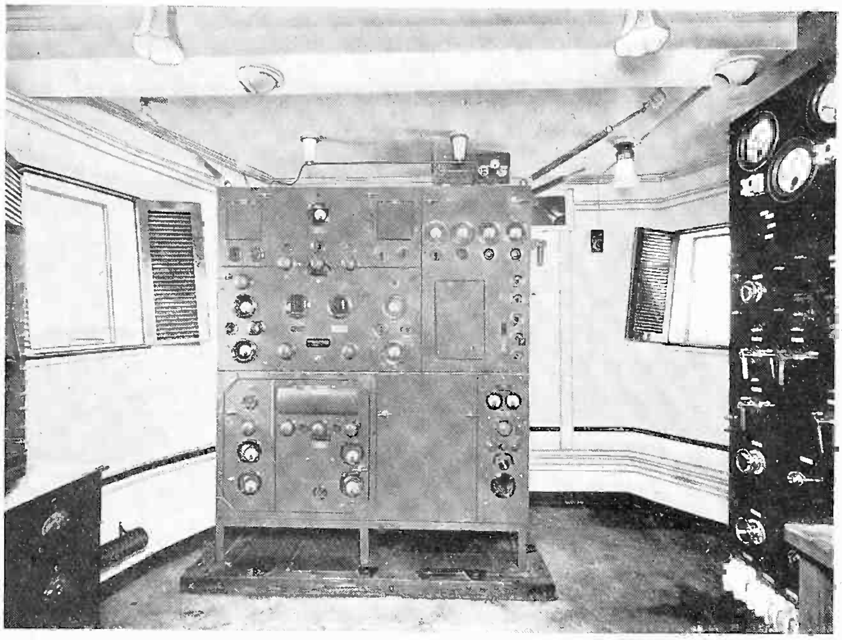


FIG. 1.

The output from the master oscillator is amplified by means of the master oscillator amplifier which comprises 6 valve stages indicated on the schematic diagram as :—isolator, 1st, 2nd, 3rd, 4th and 5th bridges. The isolator valve ensures that anode or grid current changes in later stages due to keying or modulation, cannot react on the master oscillator and cause a variation in frequency. Harmonic selection from the master oscillator takes place in the isolator stage, and the second stage of the master oscillator amplifier.

The master oscillator amplifier unit which comprises the 6 stages is mounted below the master oscillator box.

The first of the 2 power amplifiers, No. 2 magnifier, incorporates 2 MT11 S.W. valves and is mounted in the bottom right hand corner of the transmitter.

The output from the No. 2 magnifier drives the final power amplifier, No. 1 magnifier employing 2 MT12 valves in parallel. This amplifier is mounted together with the aerial circuits in the top left hand compartment of the transmitter.

Modulation of the transmitter is effected by the direct current grid method, a description of which has been given in THE MARCONI REVIEW, No. 21, page 14. Briefly the method employed is to vary the grid bias of the magnifier valve in accordance with the modulating signal, while the driving voltage on the grid of the magnifier valve is kept constant in amplitude.

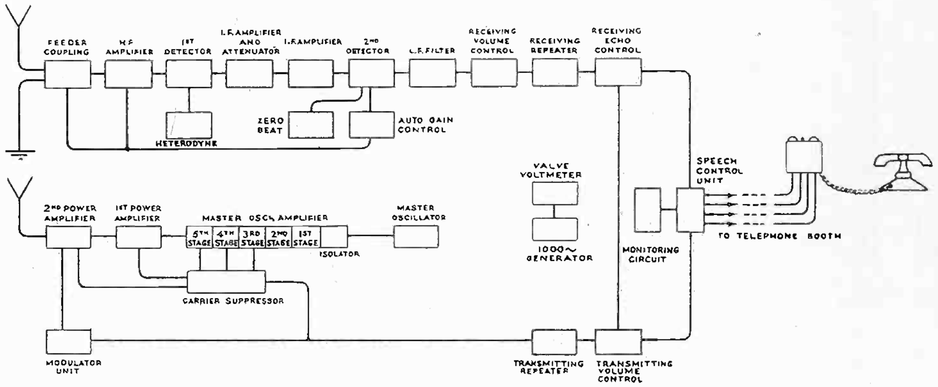


FIG. 2.

The method employed is to use the filament anode impedance of the LS5 modulator valve as a grid leak which provides an automatic bias for the magnifier. The required variations of this bias are obtained by impressing on the grid of the LS5 valve the modulating input.

The modulator panel consists of 2 LS5 valves, one as a modulating valve and the other as a Note Oscillator, which can be used for I.C.W. as a short wave telegraph transmitter. In telephony work it is not usual to key the actual transmitter, and a tone generator is therefore fitted to the ship's receiver in order that a tone may be sent to line and transmitter preparatory to passing the telephony call to the shore receiving station.

The carrier suppressor is a thermionic valve trip device, the effect of which is to so bias the grids of the No. 1 and No. 2 magnifier valves, that they take up their maximum dead loss load while the 3rd and 4th stages of the master oscillator amplifier are backed off, when no speech is being transmitted. Directly speech is passed to the transmitter this bias is removed and the carrier is immediately transmitted.

The transmitter is mounted on a special floating floor and sprung from the roof of the cabin to avoid vibration.

Adjacent to the Transmitter Cabin is the Machine and Battery Room.

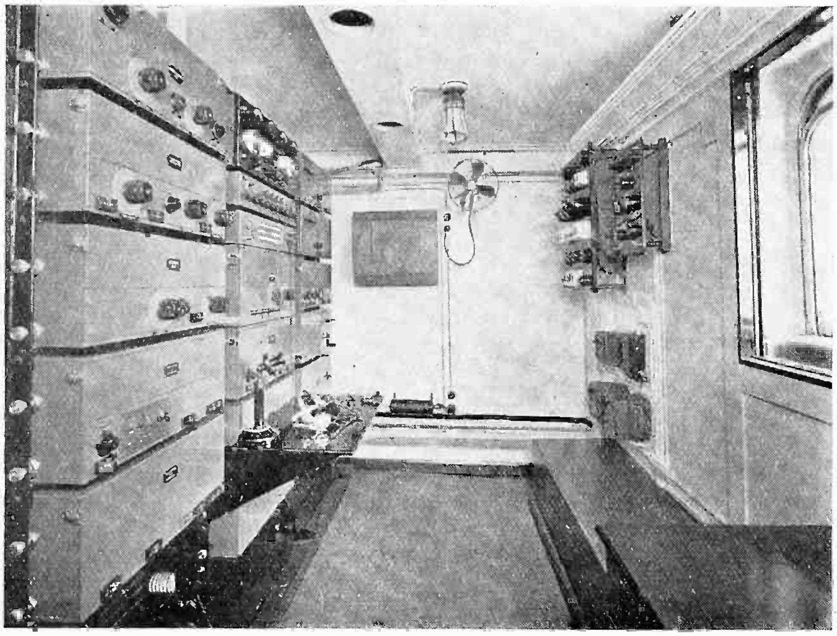


FIG. 3.

The H.T. and L.T. for the master oscillator is provided by batteries, while the H.T. and L.T. for the other circuits is provided for by machines.

In addition to telephony, provision is made for the set to be keyed as a short wave telegraph transmitter in the event of emergency, on C.W. and I.C.W.

The transmitting aerial consists of a single vertical wire 110 ft. long slung from the main aerial and brought directly to the leading-in insulator.

In addition to the aerial, an artificial load with hot wire ammeter is provided to enable the set to be tuned to the various wavelengths without being put on the air.

The Receiver.

No special mention need be made of the receiver beyond the fact that it is housed in a special cabin on the port side of the boat deck amidships and erected in a fore and aft position on a special floating floor and sprung from the roof of the cabin to avoid vibration. The aerial for the receiver consists of a single vertical wire 100 ft. long slung from the main aerial between the centre and aft funnel and brought directly to the lead-in insulator. A di-pole aerial is also installed between the forward and centre funnel for use with the receiver when desired.

A photograph of the receiver cabin is shown in Fig. 3.

WAVELENGTHS FOR AIRCRAFT COMMUNICATION

In connection with the equipping of aircraft—whether for military or civil purposes—with wireless apparatus of a type suitable to any particular requirements, the great importance of the correct choice of wavelengths is often not realised. The matter is accordingly one which is worthy of careful consideration, and it is with a view to assisting those responsible for drawing up specifications of performance for aircraft wireless equipment that this article has been primarily written.

BEFORE dealing with the technical aspect of this matter, it should be realised that, whereas the selection of any particular wavelength in a specified waveband is a matter which is subject only to the concurrence of the national authorities responsible for the allocation of wavelengths, the choice of the waveband itself will have to be made in accordance with the allocation agreed internationally by the Washington Radiotelegraph Convention of 1927. In this Convention, the complete ether spectrum has been divided into frequency groups (or wavebands), which have been allocated to various classes of wireless communications such as shipping, aircraft, broadcasting, point-to-point services, etc. It will be seen from this allocation that those wavebands which have been allotted to aircraft communications (which are clearly marked) embrace wavelengths varying from the ultra-short, at one end of the scale, to the long, at the other.

In this connection it should perhaps be made clear that the scope of the Washington Convention was to allocate wavebands for *international* services; national services are not necessarily subject to this allocation, but since wireless transmissions of a purely national service can be—and often are—a source of interference to similar services in neighbouring countries, and to international services, the Washington Convention clearly lays it down in Article 5 paras. 1 and 2 that: "The Administrations of the Contracting Governments may assign any frequency and any type of wave to any radioelectric station under their authority upon the sole condition that no interference with any service of another country results therefrom. These Administrations, however, agree to assign to stations which, by reason of their nature are believed to be capable of causing serious international interference, frequencies and types of waves in conformity with the rules for the distribution and use of waves as set forth below."

Technical Considerations.

Wavelengths available for wireless communications extend from one metre or less at one end of the spectrum to 30,000 metres or so at the other. No physical division of the spectrum into wavelengths of various categories can be made, but, by a recommendation of the meeting of the Comité Consultatif International Radioélectrique at the Hague in 1929, the spectrum was arbitrarily divided as follows :—

Ultra-short wavelengths	below 10 metres.
Short wavelengths	10—50 metres.
Intermediate wavelengths	50—200 metres.
Medium wavelengths	200—3,000 metres.
Long wavelengths	above 3,000 metres.

From the point of view of characteristics of wave propagation, however, the complete ether spectrum can be roughly divided into two groups, i.e., those wavelengths (or frequencies) at which propagation of the waves between two points on the surface of the earth occurs only along a line parallel to the surface of the earth and following the great circle path joining those points (i.e., by means of the " direct " ray), and those at which propagation occurs, in addition, by the downward reflection from an ionised layer at some height above the earth's surface (the Heaviside layer) of energy radiated from the transmitter in an upwards direction (i.e., by means of the " indirect " ray).

The first group includes both the ultra-short at one end of the scale, and the medium and long waves at the other, in the case of both of which the useful propagation normally occurs by means of the direct ray alone. In the case of the ultra-short waves (or ultra-high frequencies) the attenuation by absorption is so great that the distances over which communication can be effected, for a given radiated power, are very small ; furthermore, owing to the same reason, communication may be only possible between two points when there is an unimpeded path between these points, i.e., communication will be easiest when visual communication between the points in question would have been possible. For example, a steep hill lying in the direct path in which communication is to be effected, and under the lee of which is situated an ultra-short wave transmitter, would be liable to impede communication. For the above reasons, ultra-short wave transmitting and receiving stations for point-to-point communication should always be erected on open sites, unscreened by local objects, and preferably on high ground.

In the case of the medium and long waves, however, attenuation is relatively small, and becomes even smaller as the wavelength increases, i.e., as the frequency decreases ; the result is that, for a given power, communication can be effected over greater distances when such waves are employed than with ultra-short waves, and, furthermore, the siting of transmitting and receiving stations is not nearly so dependent upon local considerations as when ultra-short waves are employed.

The second group, in which propagation is not only effected by means of the " direct " ray but also by means of the " indirect " or reflected ray, includes the short, and under certain conditions, the intermediate and shortest of the medium waves.

With waves of this type, the frequencies are still relatively high, and attenuation, by absorption, of the "direct" ray—as in the case of the ultra-short waves—also very pronounced, the shorter the wavelength, the greater being the attenuation experienced. On the other hand, on these wavelengths certain of the energy radiated from the transmitter in an upwards direction travels, as mentioned earlier on, with barely appreciable attenuation, to the Heaviside layer, where it is reflected (or more correctly, refracted) in a downwards direction again so that it strikes the surface of the earth at a distance from the point of origin. The laws governing propagation by means of the "indirect" ray have been carefully investigated during the past five or ten years, and an enormous amount of observational work carried out and data collected and collated on this subject; while it is outside the scope of this article to deal at any length with these laws, it can be stated that the distance from the transmitter at which the "indirect" or reflected ray may be expected to strike the earth's surface again depends primarily upon (A) the wavelength (i.e., frequency) employed, and (B) the nature of the great circle path under consideration, i.e., whether it is all daylight, all darkness, or part daylight and part darkness. Provided therefore, that the necessary conditions have been complied with for the distance separating the two points over which it is desired to maintain communication by means of the "indirect" ray, such communication can be effected with a transmitter of extremely low power, since, as stated above, the radiated energy in its travel to the Heaviside layer and back to the earth's surface suffers almost inappreciable attenuation.

It will be realised, therefore, from the above, that when waves of this type are employed, energy radiated along the earth's surface will quickly be dissipated by absorption, and the range of the "direct" ray will be small for a given power transmitter; on the other hand, energy radiated in an upwards direction will be reflected back to the earth's surface again at a distance from the transmitter which may vary from about a hundred to many thousand miles, according to certain well defined laws, and the range, therefore, of the "indirect" ray can be extremely great for a given power (and hence a given weight) of the transmitter. After the (limited) range of the "direct" ray is reached, a silent zone is encountered, and this may, of course, extend for hundreds or even thousands of miles, until a point is reached where the "indirect" ray reaches the earth's surface and reception is again possible. This phenomenon is known as "skip" effect, and the distance between the useful limit of the "direct" ray and the point where the "indirect" ray strikes the earth's surface is known as the "skip" distance; reception within the "skip" zone is, of course, not possible, apart from weak signals which may be received due to scattered radiation from the Heaviside layer.

It must, of course, be realised that, in the same way as no clearly defined physical division of the ether spectrum into the various groups of waves or frequencies is possible, so the properties possessed by the various groups arbitrarily selected are not clearly defined, but merge one into the other. As wavelength increases from ultra-short to short and thence to intermediate, medium, and long, so the range of the "direct" ray gradually increases for a given power, and the "skip" distance decreases gradually from infinity, in the case of the ultra-short waves to zero in the case of the longer of the intermediate and the long waves; this transition of characteristics is shown in the figures given below, which although roughly correct, vary according to the season and to the position of the great circle route with respect to the polar regions.

Wave (metres)	Skip Distance Day (Miles)	Skip Distance Night (Miles) Summer	Skip Distance Night (Miles) Winter
15	900	5,000	Infinity
20	600	1,400	Infinity
30	300	700	4,000
40	250	350	1,500
60	*200	250	350
80	No Skip	*250	*200
100	No Skip	*250	*200

* Very variable.

With the longer of the intermediate waves and the shorter of the medium waves, particularly at night, the "indirect" ray reaches the earth's surface, at distances within the effect of the "direct" ray, and interference between the two is experienced; owing to the variable nature of the "skip" effect under these conditions, and to the relatively weak strength of the "direct" ray at the distances in question, the interference experienced takes the form of a periodic increase and decrease of strength of received signal. This change in strength of signal sometimes occurs with great rapidity and sometimes only gradually, and the phenomenon is known as "fading."

In addition to the above considerations, there are others of almost equal importance which have to be considered when selecting the most suitable wavelength for any specific requirement. For example, the reception of intermediate, short, and ultra-short wavelengths in the air presents greater difficulties than is the case with medium and long wavelengths, owing to the fact that, on these wavelengths, interference from the aircraft engine ignition system can be extremely serious; this obstacle is, however, not insuperable, since it can be overcome by carefully screening the ignition system and paying the greatest attention to ensure that every metallic portion of the aircraft is well and truly "bonded" together. The shorter the wavelength employed, the more complete must be the screening of the ignition system, and the greater the care with which the bonding must be carried out ; on the lower of the short wavelengths, not only is it necessary to screen the magneto distributors, all high and low tension leads, and all low tension switches, but the plugs themselves must be of the screened type. Reception of ultra-short wavelengths in the air is an extremely difficult matter.

While there is no difficulty from a technical point of view in so preparing the ignition system and the bonding of an aircraft, there are objections to this procedure on account of the cost of this additional work on the aircraft, the additional weight of the screened ignition system as compared with the unscreened system, and the necessity for extremely careful maintenance in order to prevent the occurrence of possible faults in the ignition system, with the consequent risk of engine failure ; on the other hand, if, from other considerations, it appears imperative to employ short wave reception in the aircraft, then the above objections are obviously outweighed by these considerations, and, provided maintenance is carried out systematically and thoroughly, entirely satisfactory results will be obtained.

Another point which must be borne in mind when selecting the type of wavelength to be employed is the necessity or otherwise for directional reception in the aircraft ; up to the present, directional reception in the air has not been found practicable below about 300 metres, with the result that, should this form of reception be essential as an aid to the navigation of the aircraft, the choice of wavelengths is limited to those in the medium, and long wavebands.

Selection of Wavelengths—Normal Practice.

Having studied at some length the technical considerations governing the choice of wavelengths, it will be of interest to observe the effect which these considerations have had upon the normally accepted practice for various classes of military and civil aircraft wireless services.

Military Aircraft.

Dealing firstly with aircraft for military purposes, these can be classified roughly as follows :—

(A) Fighter or Interceptor Aircraft.
(B) Army Co-operation Aircraft.
(C) Short distance Reconnaissance (either military or naval) or bombing aircraft.
(D) Long distance reconnaissance or bombing aircraft.

For fighter or interceptor aircraft, short range inter-aircraft communication is required, with relatively short range ground-to-air and air-to-ground communication ; since these aircraft are always single-seaters, the pilot being the sole occupant of the aircraft, the use of radio-telephony is essential. Owing to the fact also that the use of trailing aerials is precluded, on account of the necessity for aerobatics to be performed, a fixed type of aerial (which, owing to its small physical dimensions and capacity, is efficient on short and intermediate wavelengths alone) is also essential; for these reasons, therefore, intermediate wavelengths are normally employed for these aircraft, the wavelengths chosen being usually of the order of 70—130 metres; wavelengths below about 70 metres are not usually employed on account of the increased ignition interference experienced, while on those above about 130 metres it is difficult to instal an efficient fixed aerial on the small aircraft normally employed for the work.

For army co-operation aircraft, medium range ground-to-air and air-to-ground communication is required. Since the aircraft are normally two-seaters, telegraphy is usually the means of communication employed, the observer as a rule acting as W/T operator; in certain cases, such as when communicating with infantry or tanks, telephony may be used, but when communicating with artillery for ranging or other purposes, telegraphy is almost always employed. Ranges up to 20 miles may be necessary, and the use of a fixed aerial, although preferable from the point of view of aerobatics is not essential; in most countries, however, a short trailing aerial is preferred. Owing to the difficulties of reception on short wavelengths in the air, and to the limited range of the "direct" ray on these wavelengths, the use of intermediate and medium wavelengths, of the order of 150—400 metres, is normal practice for this type of aircraft.

For short distance reconnaissance or bombing aircraft (including fleet spotting aircraft) continuous communication between aircraft and the base is necessary up to a maximum distance of some 100 miles or more; furthermore, it may often be advantageous to provide the pilots of such aircraft with navigational assistance in the form of direction finding, either by means of a direction finder carried in the aircraft and taking bearings on transmissions from known ground stations, or by means of direction finders on the ground taking bearings on transmissions from the aircraft. Since such aircraft are usually two or three-seaters of medium size, the wireless equipment is not so limited by considerations of space and weight as in the case of smaller aircraft; in addition, the crew can usually include a trained W/T operator, with the result that telegraphic communication can be—and, in practice, is almost always—employed. From the above considerations, therefore, medium wave sets of medium power are almost universally employed for such aircraft, wavelengths of the order of from 500 to 2,000 metres being normally utilised.

For long distance reconnaissance or bombing aircraft (both day and night) the same considerations apply as in the case of the short distance reconnaissance or bombing aircraft, with the exception that, not only are the distances, over which continuous communication with the base is necessary, much greater (often being of the order of 300 miles or more) but, in addition, the aircraft are usually so large—particularly in the case of bombers—that the carriage of a more powerful medium wave set is possible than is the case with the short distance reconnaissance or bombing aircraft. Furthermore, it may occur that flights of such aircraft, being obviously subject to military considerations alone insofar as objectives are concerned, may necessitate the aircraft being out of touch with the base, even though a relatively powerful medium wave set is carried. For this reason an additional short wave set of relatively small power is often carried in such aircraft as an auxiliary means of communication at extreme ranges ; by judicious selection of the wavelengths used, so as to avoid " skip " effect, most satisfactory results may be attained with such auxiliary equipment.

Civil Aircraft.

Dealing now with civil aircraft, these can be roughly divided into three groups :—

(A) Light aeroplanes.

(B) Passenger (or freight) carrying aircraft employed on regular services over established air routes.

(C) Passenger (or freight) carrying aircraft employed on regular services over country where an air route organisation has been only partially established, or over long sea routes.

With regard to light aeroplanes, the development of this form of flying has mostly been along sporting and social lines ; training of pilots has also been to a great extent carried out with this type of aircraft. Up to the present, the necessity for the carriage of wireless apparatus has not been experienced, except in isolated cases such as foreign touring, special flights, etc., but it appears likely that a scheme may shortly be evolved in Great Britain whereby weather reports are broadcast by radiotelephony from various centres in accordance with a carefully organised routine, in order that pilots carrying out cross country flights may receive such reports in the air and hence be better advised of the weather conditions ahead of them than is possible at present. A maximum ground-to-air telephony range of about 80—100 miles is likely to be required, and naturally, it is of prime importance that the receiving equipment in the aircraft shall be not only as light and compact, but that it shall also be as cheap as possible ; furthermore, the use of a trailing aerial is to be deprecated if it can be avoided, on the score of the difficulty of accommodating the aerial winch and fairlead in the extremely small space available in aircraft of this type, and also because of the potential danger should pilots forget to wind in their aerials when flying low or on the point of landing.

Up to the present, the most suitable wavelength for such a wireless service has not been decided, but in view of the above considerations, the majority of opinion favours the use of a wavelength between 100 and 200 metres, since on these wavelengths an efficient fixed aerial can be designed for most modern light aeroplanes, and since, for other technical reasons, such a wavelength appears entirely suitable.

For those light aeroplanes and "taxi" aircraft which often fly along recognised air routes, the requirements to be met are, in the main, similar to those which arise in the case of normal passenger (or freight) carrying aircraft operating over established air routes, and are dealt with under that heading.

In the case of passenger (or freight) carrying aircraft employed on regular services over established air routes, the selection of wavelength is obviously dependent upon the ground wireless stations which have been erected by the various Governments concerned along that route, and with which communication will have to be carried out. Since established air routes are (in Europe, at any rate), usually international rather than national in character, the ground organisation, including wireless services, is internationally regulated; a band of wavelengths from 850 to 950 metres was accordingly allotted for this purpose by the Washington Radiotelegraph Convention of 1927, and in this band the wavelength of 900 metres has been accepted in most countries in the world as an international civil aircraft wave, in the same manner as the wavelength of 600 metres has been accepted internationally for shipping. In addition, wavelengths of 870 and 930 metres have been accepted in a number of countries as alternative wavelengths for telegraphic and telephonic communication respectively, for use when the 900 metre wave is congested. Bands in other parts of the ether spectrum were also reserved at Washington for aircraft communications, but no single wavelength other than that of 900 metres was definitely allocated for international civil aviation work.

In air routes of this type, ground stations are usually not more than 300 miles apart, owing mainly to the fact that aerodromes are necessary at this distance from one another on account of the average endurance of aircraft employed on passenger carrying work. Furthermore, owing to the facts that (A) the most direct communication between the *pilot* of such aircraft and the ground is often essential, and (B) the payload of the aircraft being strictly limited by Certificate of Airworthiness conditions, the carriage of a trained telegraph operator involves the loss of a paying passenger, with consequent financial loss, and it may often be preferred to utilise a pilot-operated telephony service rather than an operator-operated telegraphy service. In addition, the necessity for maintaining regular services under all conditions of weather often renders it extremely important that navigational aid by means of directional wireless systems should be available for the pilot of the aircraft; as mentioned earlier on in this article, directional wireless systems available in practice—with a few solitary exceptions which are only in the experimental stage at present—operate solely on wavelengths above approximately 300 metres.

From a technical point of view, therefore, apart from questions of international regulations, the use of medium or long wavelengths for this class of work is, from all points of view, to be recommended, except possibly that of the range-for-power ratio (and hence range-for-weight ratio) of the transmitting apparatus, which is considerably higher when short wavelengths are employed than with medium or long wavelengths. From the practical point of view, however, the question of wavelength has already been settled internationally, and aircraft operating companies will naturally prefer to communicate with ground stations already erected by Government authorities, rather than erect such stations at their own expense—even if such latter course were permitted by the authorities concerned, which is definitely not the case in most countries.

For passenger (or freight) carrying aircraft employed on regular services over country where an air route organisation has been only partly established, i.e., where ground facilities are few and far between, and also where such aircraft are operating over long sea routes, it may often be necessary to consider the use of short wavelengths either in place of, or in addition to, medium or long wavelengths, on account of the higher range-for-power ratio obtained on such wavelengths.

In the case of land aircraft following a sparsely organised route, short wavelengths are often employed as the sole means of communication, and provided the actual wavelength to be employed is carefully selected to suit the particular conditions obtaining along the route, and that the aircraft ignition system is fully screened, excellent results can be—and in fact have often been—obtained. Owing to various technical considerations, the use of telephony on these short wavelengths has not been found to be satisfactory over any but very short distances (i.e., within the range of the "direct" ray) unless a transmitter employing a quartz crystal type of frequency control is used to maintain the frequency (or wavelength) steady to within extremely fine limits. As a transmitter of such design is relatively bulky and heavy for a given radiated power, the use of short wavelengths as described above is confined almost entirely to telegraphic communication, and a trained operator is, of course, carried in the aircraft.

In the case of large seaplanes or flying boats operating over long distance oversea routes, communication can often be carried out with coastal or ship stations within range along the route, and such stations employ, in the majority of cases, medium wave apparatus operating on the international shipping wave of 600 metres. For this reason the carriage of medium wave apparatus is essential, particularly since an aircraft direction finder can be employed with advantage in obtaining navigational aid from these stations—a matter which is often of the greatest importance when flying long distances over sea and out of sight of land, and when depending almost entirely on dead reckoning methods of navigation.

If communication with marine air ports or bases at extreme ranges is considered necessary, however, the carriage of supplementary short wave apparatus is essential, since the use of medium wave apparatus of sufficient power to communicate over such ranges is often impracticable from the points of view of weight, size and cost. Hence, for aircraft of this type, both medium and short wavelengths are normally employed, the apparatus being capable of functioning on 900 and 600 metres on the medium waves, and on any selected short wavelength or wavelengths.

In an article of this nature it is obviously extremely difficult to do more than touch on the many aspects of a complex subject such as that of the choice of suitable wavelengths for various classes of aircraft ; it is to be hoped, however, that the information given above will serve as a rough guide to those responsible for specifying the type of wireless apparatus to be installed in such aircraft, and the opportunity is here taken to state that detailed information or advice will gladly be given at all times by the Marconi Company, both on this and other kindred subjects.

C. B. CARR.

THE VERTICAL POLAR DIAGRAM OF A MARCONI BEAM AERIAL

The calculation of the vertical polar diagrams of aerial arrays presents many more difficulties than does the corresponding calculation in the case of horizontal polar diagrams.

A method of calculation based on the analysis given in a paper entitled "Short Wave Wireless Telegraphy," Proc. I.E.E., Vol. 65, No. 366, June, 1927, is described in the following article.

THE horizontal distribution of energy transmitted from an array of aerials such as a Marconi Beam is now well known.

Measurements of the distribution of field strength taken at a distance of 10 wavelengths or so agree fairly well with the values calculated on the assumption that the currents in all the aerials of the array are equal and in phase.

So far it has not been possible to measure the energy distribution in the vertical plane, and any attempt to make such a measurement must be attended with very considerable practical difficulties.

There remains only the method of calculation of the vertical polar diagram. So far as the writer is aware, this has not yet been attempted. The calculation is one of considerably greater difficulty than that required for the horizontal plane and the reason for this lies in the uncertainty introduced by the finite conductivity of the earth. It is obvious in the first place that the earth's conductivity does not affect the *distribution* of energy in the horizontal plane, for each aerial of the array produces the same field strength at a given distance and the distribution of energy in the horizontal plane only depends on the relative phases of the fields produced (assuming all the currents equal), which do not depend on the earth's conductivity. If, however, the absolute strength of the field in terms of the aerial current is required, the effect of the earth's conductivity must be taken into account.

With regard to the distribution of energy in the vertical plane, the finite conductivity of the earth has a profound effect. Perhaps the easiest way to realise this is to consider the radiation produced by an element of current at a considerable height h above the earth's surface (Fig. 1).

At a great distance r energy arrives by the direct ray r_1 also by the reflected ray r_2. If the earth were perfectly conducting there would be perfect reflection at R and the total field at the receiver would be the sum of the field due to $i\,ds$ and that of its image at a depth h below the surface, due account being taken of the difference of phase $\left(\frac{4\pi h}{\lambda} \sin \theta\right)$ of the two fields. If, however, the earth is assumed to have a finite conductivity the amplitude of the reflected ray is less and its phase different.

The method of calculation of the vertical polar diagram consists in taking account of the sum of the elements of field strength due to the direct and reflected waves from the earth's surface.

The calculation is based on the analysis first given by the writer in Proc. I.E.E., "Short Wave Wireless Telegraphy," Vol. 65, No. 366, June, 1927, where it is shown that an extension of Sommerfeld's analysis* of the transmission of electric waves over the earth's surface may be made to yield the vertical polar diagram of a small aerial situated at any height h above the earth's surface. This analysis has recently been confirmed by the theoretical work of M. J. O. Strutt† and by W. Howard Wise‡.

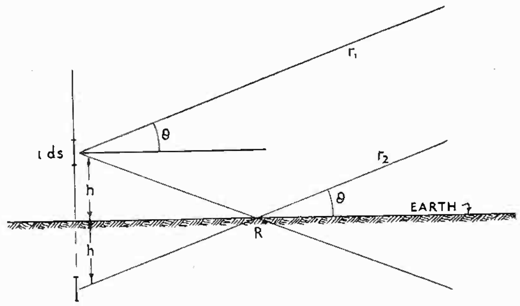


FIG. 1.

It is shown that the field due to an element $i\ dh$ at a height h above the earth's surface is proportional to the quantity

$$\cos\theta\ i\ dh \left\{ e^{-i\varphi} + \left(\frac{n\alpha - n'}{n\alpha + n'}\right) e^{+i\varphi} \right\}$$

$\varphi = \dfrac{2\pi h}{\lambda} \sin\theta$, and θ is the angle of elevation of the ray.

$$n = \sin\theta$$

α and n' depend on the earth constants in the following way :—

$\alpha = \varepsilon + 2i\sigma\lambda C$

$n' = \sqrt{\sin^2\theta + \varepsilon - 1 + 2i\sigma\lambda C}$

σ = conductivity of the earth is C G S Em. units.

ε = specific inductivity of earth.

λ = wavelength in cms.

C = velocity of light = 3×10^{10} cms./sec.

The quantity $\dfrac{n\alpha - n'}{n\alpha + n'}$ is the reflection coefficient of the earth for vertically polarised wave with angle of incidence $90° - \theta$.

In C. S. Franklin's uniform aerial the effective current in the aerial is nearly a constant. In this calculation the effective radiating current is assumed as constant, in which case the total field due to an uniform aerial of height h is

$$\cos\theta \int_0^h \left\{ e^{-i\varphi} + \left(\frac{n\alpha - n'}{n\alpha + n'}\right) e^{+i\varphi} \right\} dh$$

* Annalen der Physik 1909, ser. 4, Vol. 28, p. 665.
† Annalen der Physik 1929, 5 Folge, Band 1, Heit 6.
‡ "Bell Journal," Oct. 1929, Vol. 8, No. 4.

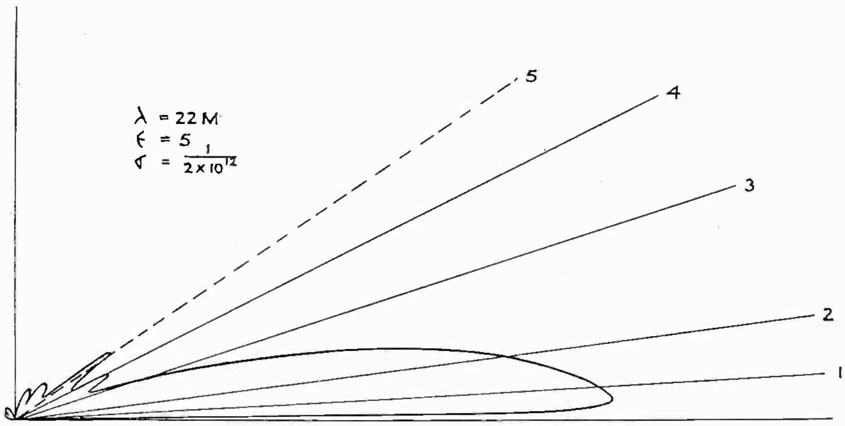
and since n, α, and n' do not contain h, this reduces to

$$\frac{1}{i \tan\theta\, 2\pi}\left[\left(1 - \frac{n\alpha - n'}{n\alpha + n'}\right) - \left(e^{-i\varphi h} - \frac{n\alpha - n'}{n\alpha + n'}e^{+i\varphi h}\right)\right]$$

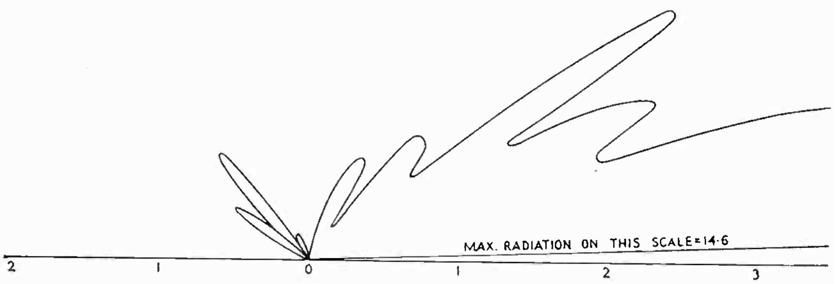
where

$$\varphi h = \frac{2\pi h \sin\theta}{\lambda}$$

The polar diagram of the simple uniform aerial of height can be calculated from this.



CURVE 1.



CURVE 2.

FIG. 2.

The polar diagram in a vertical plane perpendicular to the plane of the array of a beam aerial will then be the same. If we wish to take account of a reflector spaced a distance a quarter of a wavelength from the aerial and with currents differing in phase by $\pi/2$ we have to multiply by the factor $\{1 - \cos[\pi/2\ (1 + \cos\theta)]\}$ to get the final result of the radiation in a vertical plane of a beam aerial of height h. Some care must be taken in choosing a typical example as the computation is very laborious.

A wavelength of 22 m. was taken since the facsimile results have given evidence of a set of rays propagated on this wavelength over the transatlantic route. The angles of these rays are known and the relative energies emitted along each of these rays can be calculated when the polar diagram is known.

The value of σ the earth's conductivity was taken as $\frac{1}{2 \times 10^{12}}$ which is the value obtained at Broomfield for damp earth in the earth screen resistance measurements.

Somewhat lower values of this quantity are obtained from the results of the attenuation of broadcast waves by applying Sommerfeld's transmission theory, but as these probably include some dielectric losses in trees and vegetation the higher value $\frac{1}{2 \times 10^{12}}$ was chosen as representing the true earth's conductivity.

A value of $\varepsilon = 5$ was chosen, when the value of the conductivity is so high the choice of ε between fairly wide limits makes only little difference.

The height of the aerial was taken as three wavelengths (66 m.) in this case, and the final results are shown on curves 1 and 2. Perhaps the most striking result is the extraordinary concentration of energy in the lower angle directions. The maximum radiation occurs at only 2° elevation and practically the whole of the energy is radiated below 20°. In one respect the results may appear contradictory.

The diagram shows zero radiation along the horizontal direction. This is not meant to imply that no radiation is projected horizontally, but that at great enough distances the radiation projected horizontally is negligible compared with the radiation at a finite angle. This absence of horizontal radiation is a consequence of the high attenuation of the horizontal rays which are rapidly reduced by the earth's resistivity. This absence of horizontal radiation is a characteristic of all short wave aerials (examples are given in the curves published by M. J. O. Strutt and Howard Wise).

On this wavelength the direction of the useful rays for transatlantic transmission is given by the five lines labelled 1, 2, 3, 4, 5. The ray 5 is the upper limit of useful radiation, that is to say, energy transmitted at higher angles than this, will, in all but exceptional cases, penetrate the Heaviside layer and escape. It will be seen that the energy transmitted on the higher angle rays 3 and 4 is in general, small compared with that emitted on rays 1 and 2.

As far as the back radiation is concerned the main loops are at 35° and 50°, and the maximum amplitude ratio is only $\frac{1}{142}$. In general the direction of the lowest loop is above the cone of useful radiation. This may account for the fact that practically no echo is ever heard on WAJ a 22m station at New York. If, however, the aerial were tilted back some 15° as in some recent experiments, the lowest back angle loop might come within the cone of useful radiation and echo might occur under suitable transmission conditions.

T. L. Eckersley.

MARCONI NEWS AND NOTES

ULTRA SHORT WAVE WIRELESS TELEPHONY

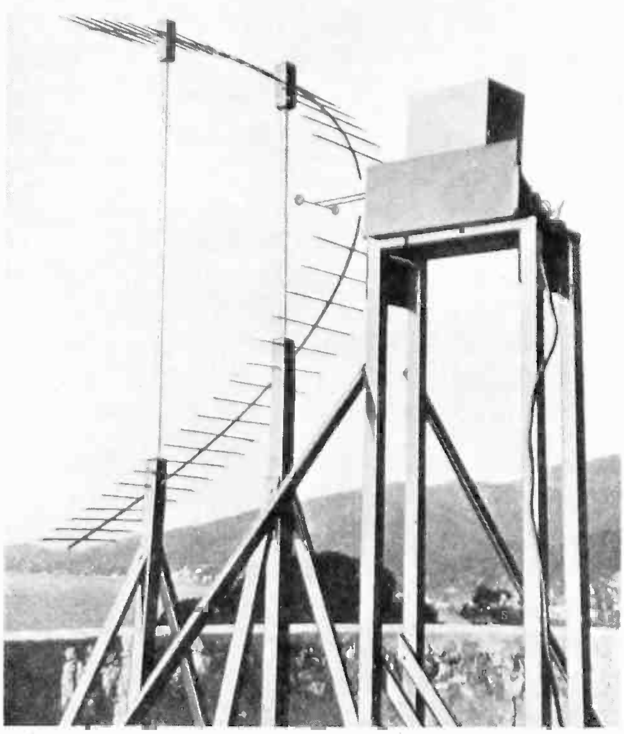
IN the presence of representatives of the Italian Government, an official demonstration took place on November 19th in Italy, between Santa Margherita Ligure and Levanto—a distance of 25 miles—of the new Marconi quasi-optical, ultra-short wave radio-telephone system. The wavelength used was only 50 centimetres (the same as that employed in the previous demonstration carried out between Santa Margherita Ligure and Sestri Levante over a distance of 11 miles), corresponding to the enormous frequency of six hundred million cycles per second.

The success of the demonstration was all the more complete because, although the range had been increased from 11 to 25 miles, the margin in the signal strength was such as clearly to indicate to all present that the apparatus used was capable of covering a considerably greater distance.

Early Experiments with Ultra-Short Waves.

In an interview granted immediately after the demonstration to representatives of the Press, His Excellency the Marchese Marconi made the following interesting statement :—

" Since 1896, when I was already experimenting with wavelengths of 20 centimetres, I had no doubt in my mind but that the short waves, which are called quasi-optical because they behave very much like the waves of visible light, would one day come into use for commercial communications. The results of those very early tests were confirmed by the more recent experiments I carried out at Leghorn during the world-war using a wavelength of 50 centimetres. However, nobody, myself included, had then succeeded in producing ultra short wave apparatus sufficiently powerful, economical and reliable to justify its immediate use for public telephone or telegraph services over suitable distances.



Marconi quasi-optical ultra-short wave transmitter.

Public Telephone Services in Italy.

"During the last six months, my assistants, particularly Mr. G. A. Mathieu, and myself have been concentrating our efforts towards a commercial solution of the problem, and many unexpected and valuable discoveries have been made. I would, therefore, ask you not to consider this demonstration as a mere scientific experiment, but as a test of a new practical and commercial radio-system which will very shortly be used for public services in Italy. Owing to its simplicity the new system is very moderate in price and in running costs: it will thus soon afford to the inhabitants of many small islands scattered in the Mediterranean a reliable telephone service which they could not, heretofore, enjoy in consequence of the high cost of the submarine cable telephone installation."

Requested to state whether it was correct that the application of this "quasi-optical" wave was strictly limited to very short distance communications, Marchese Marconi added: "Well, at the present stage of our knowledge I do not anticipate a reliable range of more than about 100 miles; but this is, of course, a very useful range in itself, and could be very greatly increased by making use of relays or repeaters wherever possible."

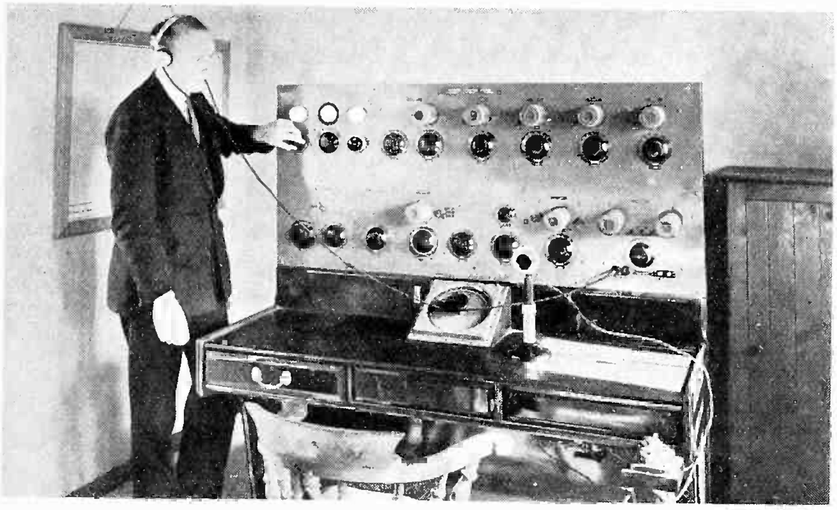
Wireless and Night Flying.

WIRELESS direction finding, which enables pilots to be informed of their position in the air during foggy or cloudy weather, is one of the most valuable services of wireless to aviation. By its aid, a number of flights have been made between London and the Continent, during which the pilots have scarcely been able to see the ground throughout the journey, but, reliable as it has proved under these conditions, wireless direction finding has hitherto been subject to one limitation. It was subject to errors during the hours of darkness, and particularly at sunset and sunrise, due to the natural phenomenon of the irregular polarisation of wireless waves at these times.

Realising the importance of providing a direction finder capable of giving accurate bearings at all times of the day and night, particularly in view of the probable extension of night flying services in the near future, the Marconi Company has now developed a direction finder to overcome this "night effect."

Exhaustive tests have demonstrated that this apparatus, known as the Marconi-Adcock direction finder, is as reliable during the most critical periods of "night effect" as is the well-known Bellini-Tosi apparatus under normal conditions.

The first station of this type to be erected has been built by the Marconi Company for the Air Ministry direction finding station at Pulham, Norfolk, which, in conjunction with the wireless direction finding station at the London Air Port, Croydon, operates the direction and position finding service for aircraft on the London-Continental air routes.



Marconi-Adcock Direction Finder at Pulham.

During a night flight specially arranged by the Air Ministry, fourteen observations were made by an aircraft transmitting signals from known positions so that a check could be kept. The distance in every case was in the neighbourhood of 100 miles, and the accuracy of the new direction finder was complete, although the ordinary system of wireless direction finding was, at the time, most unreliable even over much shorter distances owing to "night effect."