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THE MARCONI-ADCOCK DIRECTION FINDER

Readings on the normal type of Direction Finder employing frame or loop aerials are subject to considerable inaccuracy owing to the prevalence of so-called "night effect."

The following article presents a short historical survey of "night effect," and describes investigations which finally resulted in the full understanding of the phenomena.

A brief description is given of a practical Direction Finder embodying the necessary requirements for accuracy under conditions of "night effect" and curves are shown comparing its performance with a standard Bellini-Tosi system.

The commercial design of the new Direction Finder, is well advanced, and a thoroughly practical instrument, simple in conception, and capable of an accuracy hitherto not possible will shortly be placed on the market.

AT the present time practically all commercial radio direction finding systems employ rotatable frame aerials or fixed loop aerials in conjunction with a goniometer.

During the daylight period, which is defined as that between one hour before sunrise and one hour before sunset, such direction finders give true bearings of high accuracy. Outside this period, however, grave discrepancies between the radio direction and the actual bearing of the transmitting station are possible owing to the existence of what is termed "night effect."

Stated briefly it may be said that the accurate functioning of direction finding systems employing loops or closed coils requires :—

(1) That the path of the radiation from the transmitting station lies on the great circle connecting the two points.

(2) That such radiation is normally polarised, *i.e.*, that the electric force is vertical and the magnetic field parallel to the earth's surface.

Investigators have proved that the first condition is always maintained on wavelengths above 100 m., but that the second requirement only exists during such time that the path between the transmitting station and D.F. receiver is entirely in daylight. During the other period the radiation, although following the great circle path between the two points, may arrive with any angle of polarisation and also at any angle of incidence with the earth's surface. Thus co-ordination between the action of the frame or loop aerial and the bearing of the transmitting station no longer exists.

Summarising, the frame or loop D.F. is an instrument whose indication is controlled by the degree of polarisation of the incoming radiation, combined with its direction of arrival. When this is entirely normally polarised, the indication coincides truly with the great circle path linking the transmitting and receiving stations, but if, as is the case during night periods, any abnormally polarised component exists in the radiation, the indication bears little or no relation to the true bearing of the transmitting station.

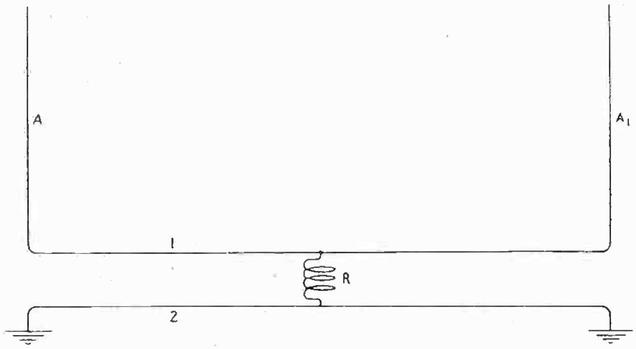

Fig. 1.

History.

The fact that the directional indication as recorded on loop or closed coil direction finders, was a function of polarisation of the radiation was simultaneously observed by Adcock and T. L. Eckersley by comparing the actual and apparent daylight bearings of aeroplanes transmitting with trailing aerials. The phenomenon was referred to as "aeroplane effect."

The outcome of Adcock's work was that in 1919 he filed a patent describing a direction finding system which theoretically was practically only receptive to the normally polarised component of the radiation, and which consequently overcame "aeroplane effect." Adcock, in his system, went back to the very earliest form of directive aerial arrangement, *i.e.*, simple vertical wires suitably spaced, as such aerials respond only to normally polarised radiation. The difficulty, which Adcock recognised, was that the horizontal lead necessary to convey the energy from these aerials to the goniometer would pick up any abnormally polarised component of the radiation and introduce error. The novelty of his invention was the arrangement of the horizontal lead in from each aerial in such a manner that any E.M.F. induced by the unwanted component was balanced out by virtue of the equal and opposite electrical configuration of this portion of the circuit. The scheme is shown in Fig. 1, in which A and A1 are the vertical aerials, R field coil of the goniometer and 1 and 2 the method of leading in the current from A to R.

It will be seen that any E.M.F. induced directly in the horizontal combination will largely balance out. Obviously for an exact balance to be realised, the electrical impedance of the earth connection must exactly balance that of the aerial, as this is the only condition in which the current distribution in the upper and lower horizontal limbs will be equal, and because this could not easily be obtained is probably one reason why the system did not immediately develop commercially.

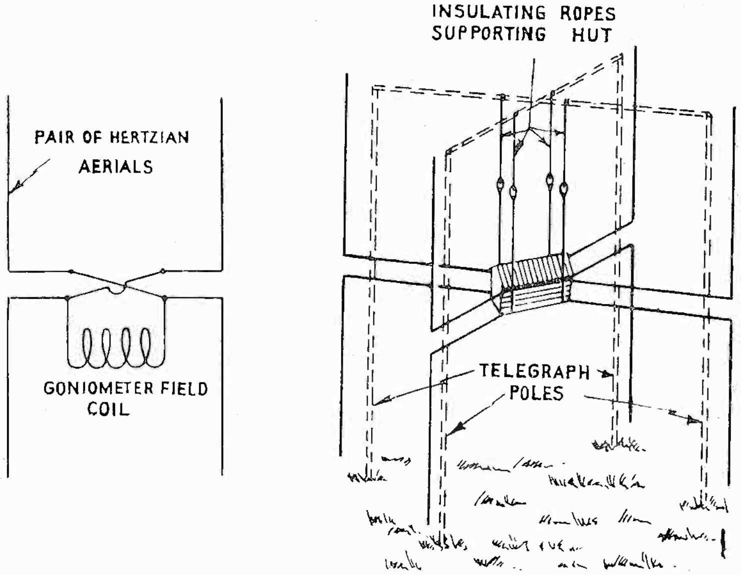

FIG. 2.

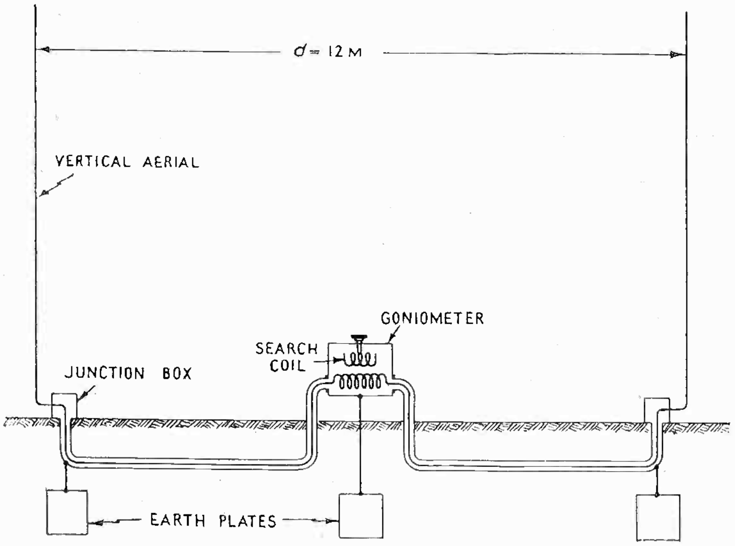

FIG. 3.

T. L. Eckersley continued his own experiments and these culminated in a paper published in the "Radio Review," Vol. II., 1921, pp. 60-65 and 231-248, in which he definitely proved that night errors could be accounted for by the presence of an abnormally polarised component in the radiation. The only point that was not proved at this period was whether or not, in addition to the error introduced by abnormally polarised radiation, slight errors were present due to lateral deviation of the radiation from the great circle path.

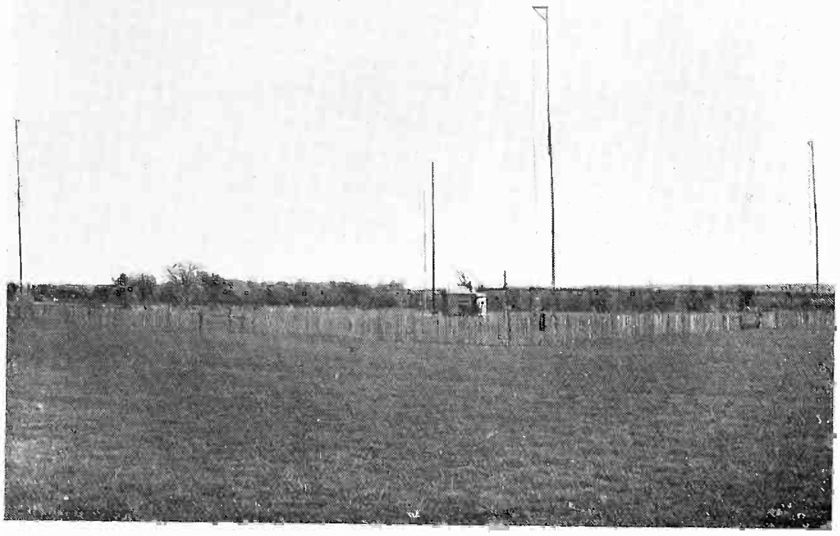

FIG. 4.

The following years were taken up in the development of accurate and simplified direction finding apparatus, the trend of which was largely governed by shipboard requirements, as although such a system as that suggested by Adcock was of great interest, it was recognised that it had no application to the most urgent and important field of direction finding, *i.e.*, the sea. The Marconi aperiodic loop system, together with the application of heart-shape reception for indicating the true sense of the signals was therefore commercially perfected and this system is still recognised as the most practical and accurate instrument for use at sea.

The Adcock idea, with the exception that it was utilised for obtaining experimental evidence of transmission phenomena, lay dormant until 1926, when Dr. Smith Rose and Barfield of the Radio Research Board gave particulars of an Adcock direction finder which was arranged in such a manner that it was practically immune from the reception of abnormally polarised radiation, and the results obtained confirmed that bearings of a very high order of accuracy were recorded under all conditions of day and night. This immunity was attained by arranging the Adcock aerial system in an absolutely symmetrical manner and entailed elevation of the receiving hut containing the goniometer. The arrangement as employed is illustrated in Fig. 2.

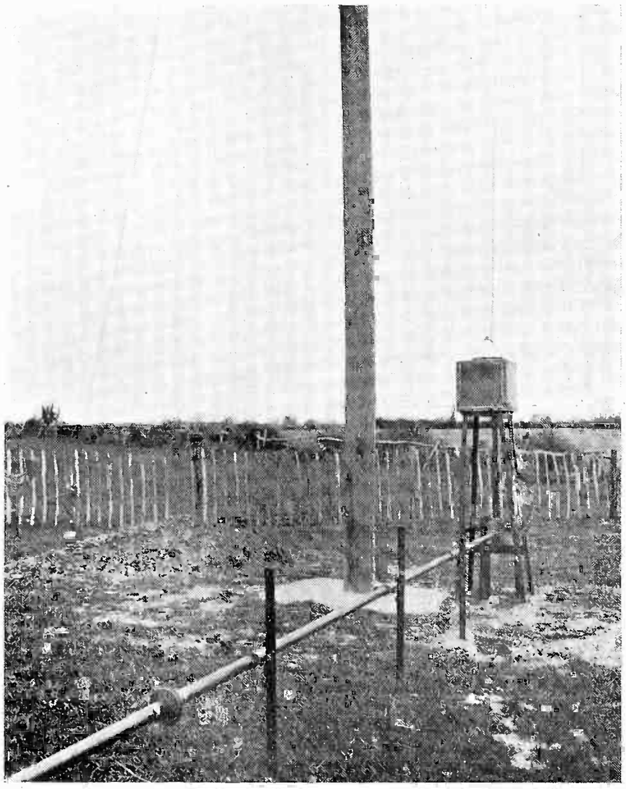

FIG. 5.

These experiments made one important contribution to already established knowledge of radio direction finding, namely that under normal conditions lateral deviation of the radiation from the great circle path was never recorded, and confirmed, that any direction finding system which eliminated the abnormally polarised component of the radiation would give true bearings during night periods. Unfortunately the elevated position of the hut rendered this arrangement impracticable from a commercial point of view and it is only quite recently that the system has been developed to a more practical form, in which the hut containing the radiogoniometer is situated at ground level.

Recent Developments.

For the investigation of short wave transmission phenomena the Marconi Research Department developed a direction finder of the Adcock form, in which the arrangement of the aerial system was on a thoroughly practical basis. A full description of the apparatus and results of the experiments were given by T. L. Eckersley before the I.E.E. in April, 1929. This modified Adcock system is illustrated in Fig. 3. It will be observed that instead of attempting to balance out any

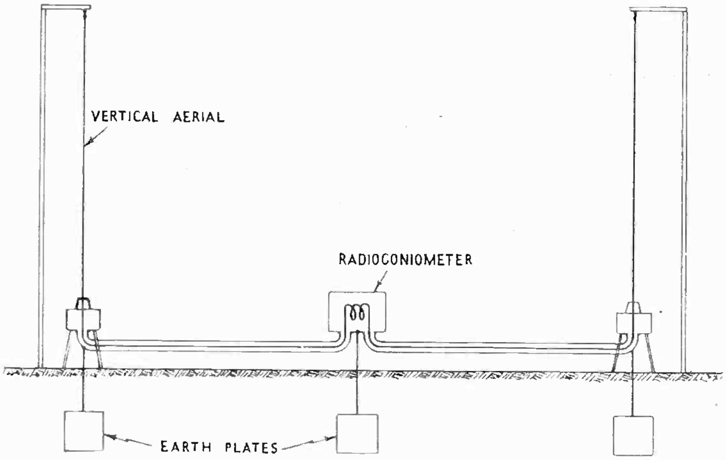

FIG. 6.

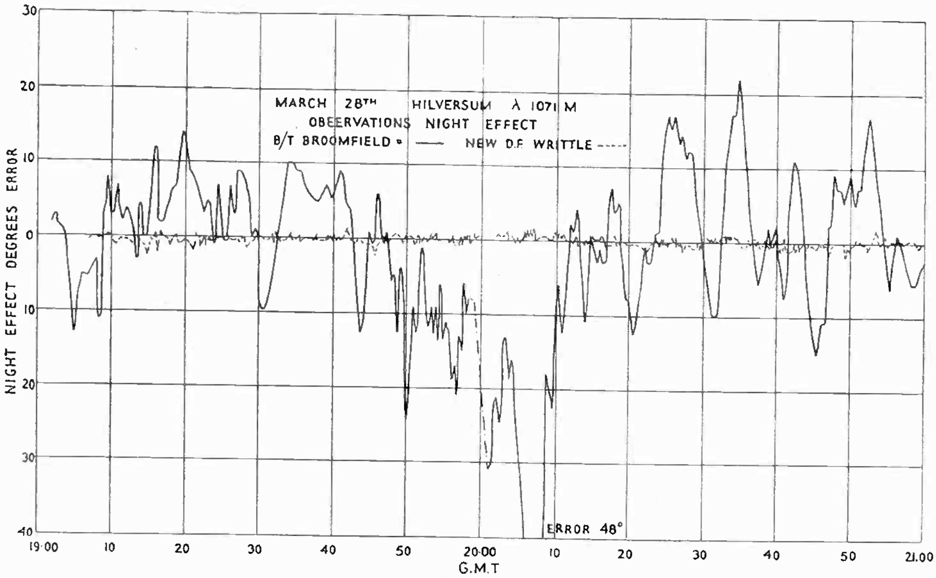

FIG. 7.

pick-up on the horizontal leads, these have been arranged in such a manner that they are to a very high degree non-radiating and therefore outside the influence of incoming electric waves.

Short wave radiation, except for very short distances, always has an abnormally polarised component, or in the nomenclature of practical direction finding, a permanent condition of night effect. This adaptation of the Adcock principle was nevertheless so successful in indicating the incoming direction of short wave radiation that it was thought the same arrangement applied to direction finding on the medium wavelengths would result in a practical instrument which would be largely free from night effect errors. It was therefore decided to set up an experimental station and owing to the increasing importance of producing reliable direction finders as night navigation aids for aircraft, the operating wave band chosen was around 900 to 1,000 metres.

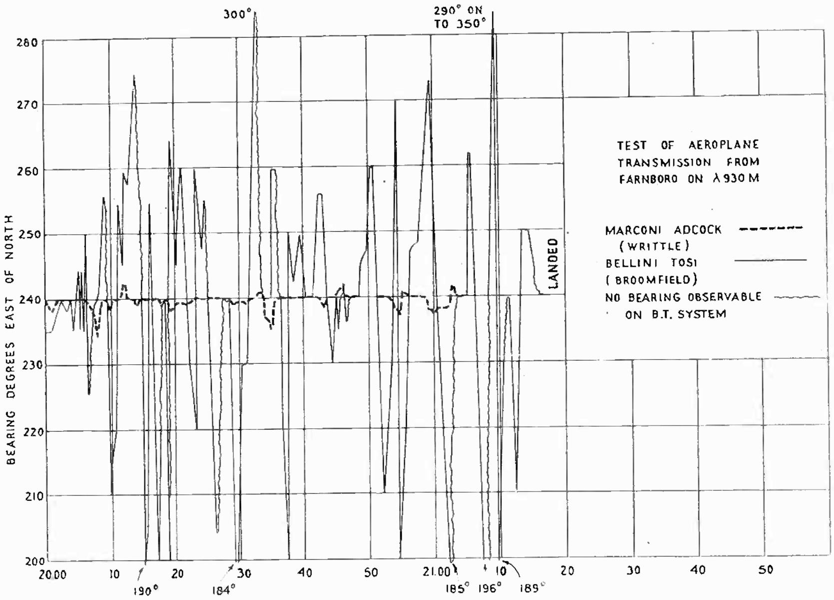

FIG. 8.

Four 70 ft. wooden masts were therefore erected at the corners of a square, the diagonals of which were 300 ft., corresponding to an approximate electrical separation between the aerials of one-tenth wavelength, or 36° on 1,000 m. Each of the aerials terminated in a screening box placed about 5 ft. above the ground, and in the same vertical line as the aerial. An electrical connection was made from each aerial to the goniometer, which was located in a hut central to the system, by means of a single conductor completely shielded in a copper tube and carried about 2 ft. above ground level. The reason for using copper tube feeder for these connections instead of buried cable was that with such an arrangement a much greater degree of electric symmetry can be attained, and this is important from the point of view of accurate direction finding. The goniometer was contained in the screening box, to which each feeder was terminated. The system was then earthed at the centre, and each feeder in the middle and also at the aerial end. In this manner the whole of the horizontal portion of the aerial system was rendered immune from the influence of any abnormally polarised component of the incoming radiation. A general view of the experimental station is given in Fig. 4, and the method of terminating at each vertical aerial in Fig. 5. Fig. 6 is a diagrammatic representation of one pair of aerials and their feeders and also illustrates the method of terminating these directly to the screening box containing the radiogoniometer. The latter was of standard form, close coupled, and designed for aperiodic working of the aerial system. The tuned search coil circuit was coupled to a very simple amplifier consisting of two screen grid high frequency stages, detector and double note magnifier.

Simultaneous observations were taken over a period on the Marconi-Adcock system and a standard Marconi Bellini-Tosi loop direction finder.

A graph combining a typical record is given in Fig. 7. The graph does not indicate in full measure the advantages of the new instrument as, in addition to the large error in the true bearing, which obtains with the Bellini-Tosi loop system during the night, there is very often considerable flatness for appreciable periods during which it is not possible to take bearings. This condition is not encountered on the Marconi-Adcock system and the readings, even under the worst conditions of night effect, are relatively sharp, and on wavelengths of the order of 1,000 metres it is possible to guarantee an accuracy of bearing of 2° to 3°.

This result is a very big advance in practical direction finding, and one which we are confident will meet the requirements of aiding aircraft at night. In this connection the graph of Fig. 8 is interesting. It represents a simultaneous record taken one hour after sunset of the position of an aeroplane transmitting with long trailing aerial on a wavelength of 930 m. from a distance of 60 miles. The aeroplane maintained its position to within a few degrees during the whole of the flight. As will be seen this fact was accurately recorded on the Marconi-Adcock system, while at the same time the record taken on the loop was, for all practical purposes, useless.

N. E. Davis.

MARCONI MARINE SHORT WAVE RECEIVER

TYPE 372

The short wave receiver, type 372, described below, has been designed for use on board ship in the many cases where reception on waves of 14 to 100 metres is necessary.

The outstanding features of this receiver are simplicity and ease of control. An oscillating detector is employed where reception of C.W. is desired, and oscillation can be easily controlled by a condenser.

The set is very efficient and represents a considerable advance in short wave marine receiver design.

THE Marconi type 372 receiver is designed for ordinary marine short wave working over a waveband of 14 to 100 metres. As will be seen from the diagram of connections, Fig. 1, it employs three valves, namely, a screen grid valve between the oscillating detector valve and the aerial, in order to decrease to a minimum the amount of energy radiated from the receiving aerial when reception is taking place, a detector valve, and one note magnifying valve, having an output transformer in its anode suitable for use with low resistance telephones.

The receiver is arranged to work on 72 volts H.T. with a tapping of 48 volts for the screen grid of the screen grid valve.

Among the important features incorporated in this receiver are the method of wave-change by means of a switch, the use of anti-induction chokes in the battery leads, and a double condenser in the tuned anode circuit, in order to decrease noises to a minimum.

To aid reception, a milliammeter is inserted in the anode of the detector valve, while a voltmeter across the filament of the valves indicates when the filaments are being supplied with the correct voltage. The instrument is mounted on a rigid metal panel and a baseboard. All component parts of the instrument are attached to this panel and baseboard, and the whole of the receiver is housed in a strong metal case.

By unscrewing the screws on the edge of the front panel, the receiver may be entirely withdrawn from its case, thus rendering a detailed examination easy.

In order to assist in any change of valves or to permit a rapid inspection of the receiver, the top of the box is made in the form of a lid hinged at the back.

The metal front of the receiver is covered with a black bakelite panel on which is engraved the function of each control knob.

Power Supply.

The receiver is designed to work on 2-volt valves of the following types :—

(*a*) Screen Grid Valve, S.215.
(*b*) Oscillating Detector Valve, H.L.210.
(*c*) L.F. Amplifier Valve, L.210, or Pentode Valve type P.T.235.

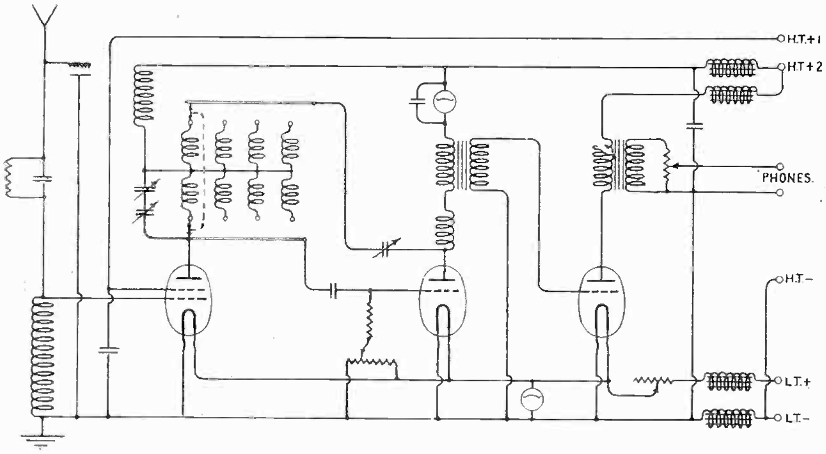

FIG. 1.

As will be noticed from the diagram of connections of this receiver, both the high tension and low tension supplies are taken through chokes embodied in the receiver. The resistance of these chokes on the low tension circuit is approximately 6 or 7 ohms, and hence the fall of voltage in these chokes prevents the use of a 2-volt battery when utilising 2-volt valves.

To overcome this difficulty, a filament rheostat has been incorporated in the positive side of the L.T. supply, between the positive L.T. supply and the valves, together with a voltmeter which is connected directly across the filaments of the valves.

In this manner, it is possible to make use of a 4-volt or 6-volt battery, whichever is more suitable for lighting the filaments of the 2-volt valves, the filament rheostat being utilised to maintain the filaments of the valves at 2-volts as indicated by the voltmeter.

The filament rheostat is arranged to be broken when turned full round to its "off" position, and therefore, in order to switch off the set and prevent unwanted consumption of current, it is only necessary to rotate the filament rheostat to the end of its travel in an anti clockwise direction.

It is permissible to use 4-volt or 6-volt valves of equivalent types to those cited above, but it will, of course, be necessary in this case to use 6-volt or 8-volt supply for the filaments of these valves.

Similar precautions to reduce induction interference, which may be picked up on battery leads, are taken with regard to the high tension supply, and in order to make full use of this arrangement, the negative high tension terminal and the negative low tension terminal should not be joined together external to the set, unless this is unavoidable.

In the case of the high tension chokes, the resistance is insufficient to cause a serious drop of voltage in the high tension supply, and therefore no adjustment is made in the high tension voltage to counteract the effect of the chokes.

FIG. 2.

No choke is inserted in the screen grid high tension supply, but a condenser is placed across the screen grid to earth.

Aerial Circuit.

The aerial circuit consists of a simple semi-aperiodic arrangement. The aerial is connected direct to the terminal marked AE on the receiver, and from that terminal passes through the series condenser and the high frequency choke to the earth terminal marked E.

Across the series condenser in the aerial, is placed a static leak, to prevent accumulation of static charge on the aerial.

In addition to this static leak, a spark gap is placed between the aerial terminal and the back of the earthed receiver panel. This spark gap will deal adequately with sudden heavy charges which may accumulate on the aerial during stormy weather, and which otherwise might cause repeated breakdown of the static leak.

The aerial side of the high frequency choke is connected directly to the grid of the screen grid valve.

No tuning of the aerial is attempted as signal strength from the main aerial of a ship is generally more than adequate for the requirements of short wave traffic, and it eliminates the necessity of utilising two tuning condensers, which is a serious obstruction to rapid searching under marine conditions.

Tuned Circuit.

The reception of C.W. signals on this short wave receiver is obtained by means of the well-known method of utilising an oscillating detector valve.

The oscillating circuit is placed in the anode of the screen grid valve and is connected to the grid of the detector valve by means of a grid condenser and grid leak. One end of the grid leak is connected to a potentiometer so that smooth reaction may be obtained on any wavelength within the range of the receiver, by selecting a suitable position on the potentiometer.

Reaction is obtained by means of a variable condenser coupled between the choke in the anode of the detector valve, and a reaction winding placed adjacent to the tuning inductance in the tuned circuit of the anode of the screened grid valve.

In the anode of the detector valve is inserted a low frequency transformer and a milliammeter. This latter enables reaction to be obtained and controlled with the smoothest possible adjustment, and is an important aid to the reception of signals under bad conditions.

In the anode of the screen grid valve, in addition to the tuned circuit, is inserted a small high frequency choke. The purpose of this choke is to enable very smooth reaction to be obtained.

It has been found desirable to utilise four stages of tuning to cover the wave-range of 14 metres to 100 metres. The first of these tuned stages covers a waverange of approximately 14 to 23 metres, the second approximately 20 to 40 metres, the third approximately 30 to 60 metres, and the fourth stage 50 to 100 metres approximately.

The difficulty of using plug-in coils has been overcome by means of a switch on which are mounted the tuning and reaction coils for the four stages.

Precautions have been taken with regard to the tuning condenser to prevent the possibility of noises creeping in during the process of tuning owing to slight variations of contact between the rotor and the fixed terminal to which the rotor is connected. To overcome this, two condensers are arranged in series. The rotors of the two condensers, both mechanically and electrically, form one unit. This rotor is insulated at both ends from the frame of the condenser. The two sets of fixed vanes are separately mounted on heavy insulation, and are entirely separate from one another.

By utilising this method of making the tuning condenser for short waves, it is possible to carry the wires from the inductance to two fixed points on the tuning condenser.

Experience shows that this method of connecting up a short wave tuning condenser gives extreme freedom from noise.

L.F. Circuit.

The rectified low frequency signal obtained in the anode of the detector valve is transferred by means of an L.F. transformer to the grid of the low frequency amplifying valve. As it is unnecessary in telegraphic work to consider the importance of quality, a grid bias battery is dispensed with, and the grid of the low frequency output valve is biased directly on the negative side of the valve.

In the anode of the L.F. amplifying valve is inserted a step down transformer, which is suitable for use in conjunction with low resistance telephones.

It will be noticed that the telephones are not connected directly across the secondary of this transformer, but via a potentiometer to the transformer.

The potentiometer serves as a volume control, and is extremely useful under conditions in which fading seriously upsets the sensitivity of the ear of the operator.

One side of the telephone is connected directly to earth so that there is no chance of the operator obtaining shocks through the breakdown of a telephone transformer.

THE DIRECT CURRENT GRID METHOD OF MODULATION

The methods of amplitude modulation in common use may be broadly classified under two headings :—

(1) *Full power anode modulation.*

(2) *Power magnification of modulated grid input.*

The following article deals with a method which falls under the second heading. It is one in which modulation of the grid input is obtained by modulation of the grid bias.

The theoretical possibilities of the method are examined and the limitations experienced in practice are discussed and illustrated.

Comparisons are drawn between this and other methods of modulation.

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1. Introduction.

LIKE all other methods of amplitude modulation the Direct Current Grid Method aims at achieving a linear relationship between variations in the instantaneous value of audio frequency input voltage from a microphone source and the resulting variations in the instantaneous value of aerial current.

The method depends, fundamentally, on the fact that if the driving voltage impressed on the grid of a magnifier valve be maintained at a constant amplitude and the grid bias be varied in magnitude, then, ideally, the resulting variations of both the D.C. input to the valve anode and the efficiency of conversion to A.C. bear a linear relationship to the variations in grid bias.

It may be noted in passing that it follows from the last paragraph that the method is not applicable to a self-oscillator, but only to transmitters comprising a master-oscillator and one or more stages of magnification.

For varying the grid bias of the magnifier stage at audio-frequency the method employed in practice is to use the filament-anode impedance of a small triode as a grid leak which provides an automatic bias ; the required variations of this bias are obtained by impressing on the grid of the triode the output from a microphone, suitably amplified.

2. Basic Principle.

In order, however, to simplify the examination of the basic principle, as defined in the second paragraph, we will consider first the case of a magnifier stage in which grid bias is provided by a battery, and trace the relationship under ideal conditions, between the bias on the one hand and the D.C. input, efficiency of conversion to A.C. and aerial current on the other.

We will take as an example the magnifier stage illustrated in Fig. 1, in which the anode potential V_B, is 2,500 volts and in which the driving voltage V_D impressed on its grid from the previous stage—a self-oscillator, O, in this case—has a constant amplitude of 600 volts peak. Grid bias is provided by the tapped battery G.B.

We will assume that the V_p I_p characteristics of the magnifier valve are as drawn in Fig. 2, from which it will be seen that at $V_p = 2{,}500$ I_p will be zero when $V_g = -150$. If, therefore, sufficient bias is provided by the battery G.B. to prevent the grid from becoming less negative than -150 volts at the positive peaks of the driving voltage V_D, there will be no D.C. input and consequently no A.C. output. This is one limit of the possible load excursion and may be denoted by a point, L_1 on the V_p I_p surface at $V_p = 2{,}500$, $I_p = 0$.

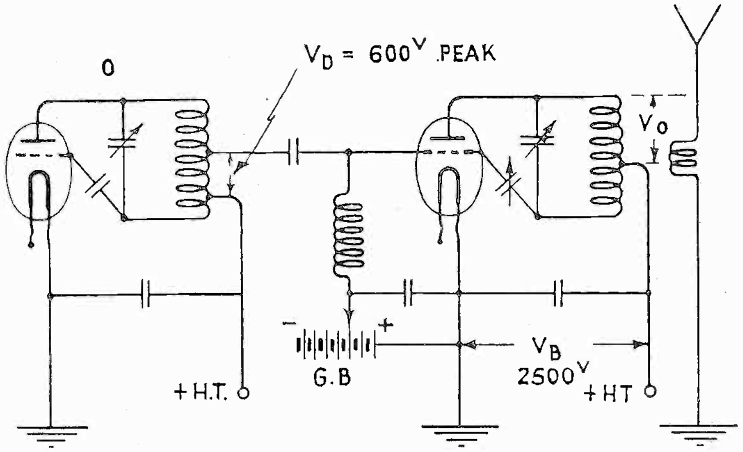

FIG. 1.

The other limit, ideally, of the possible load excursion is reached when the bias from the battery, G.B., is reduced to the point where the excursions of the grid, due to the positive peaks of the driving voltage V_D, give rise to a peak value of I_p which fulfills the following conditions :—

(1) is equal to the total emission of the magnifier valve ; or

(2) corresponds to an A.C. output such that the peak value of the A.C. voltage V_o across the output circuit is equal to V_B.

In practice, neither (1) nor (2) is entirely attainable, and for our example we will assume that the upper limit of the possible load excursion is reached when peak $V_o = 2{,}200$, and that this corresponds to a peak value of $I_p = 400$ m/a. The exact value of peak I_p will depend upon the ratio (peak I_p)/(RMS I_p), the electrical constants of the circuit and the frequency.

Since V_B and V_o are in opposition when I_p is at its peak value, we can plot $I_p = 400$ m/a, against $V_B - V_o = 300$ volts on the I_p V_p surface, and this point, L_2, will represent the upper limit of the load excursion.

For intermediate values of V_o there would be corresponding proportionate RMS values of I_p. Since we are examining the process operating under ideal conditions we will assume for the moment that the ratio peak I_p/RMS I_p is constant, in which case the locus of the points of intersection, on the V_p I_p surface, of related values of peak V_o and peak I_p will be a straight line passing through the two points

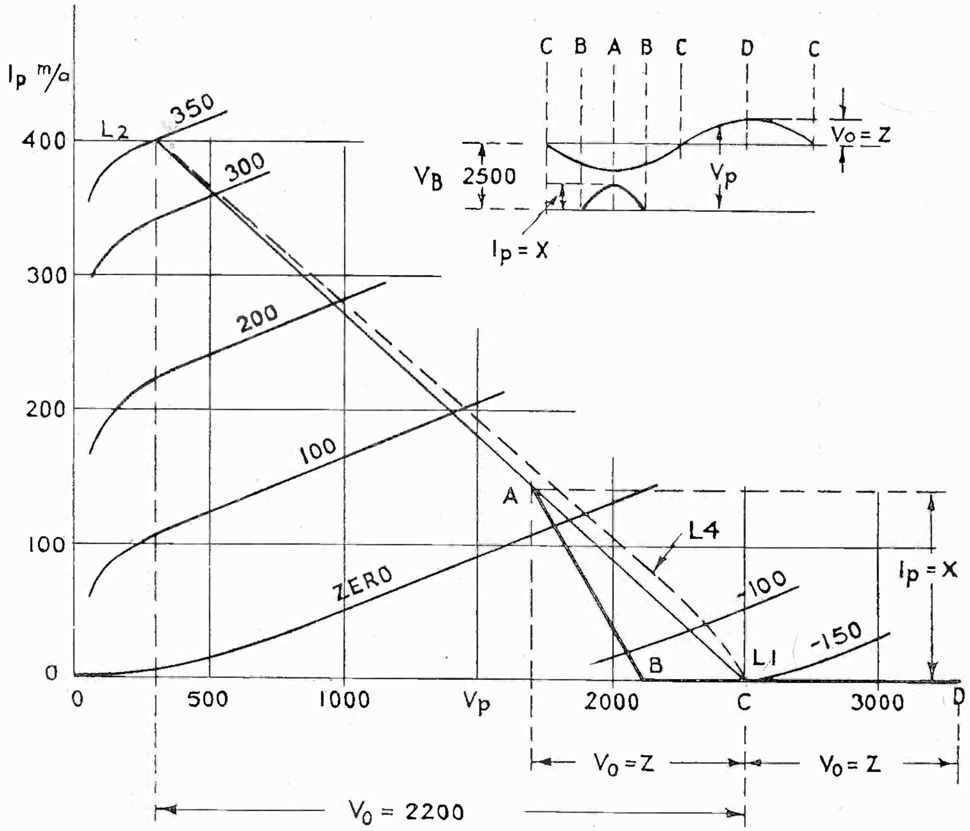

FIG. 2.

L_1 and L_2, representing respectively zero input and maximum input.

If this locus be transferred to the V_g I_p surface, Fig. 3, we can see clearly what bias would be required from the battery G.B., Fig. 1, to set the magnifier valve for any desired input.

For instance, if the bias be adjusted to —750 volts, then the positive peaks of the driving voltage V_D will carry the grid only as far as —150 volts and there will be zero input. If the bias be adjusted to —250, then at the positive peaks of V_D the grid will swing to +350, which is the required grid excursion to give $I_p = 400$ m/a at $V_p = 300$ volts, *i.e.*, the condition for maximum practical input for the magnifier stage under consideration.

Therefore, by varying the voltage of the bias battery, G.B., from —750 to —250—the driving voltage remaining constant at 600 volts peak—we should carry the valve through every HF. operating condition from that corresponding to zero input and output to that for maximum input and output.

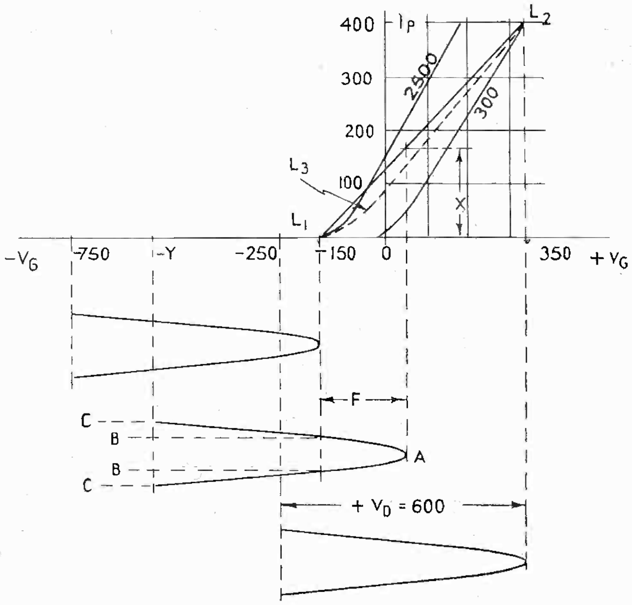

FIG. 3.

One such HF. operating condition is illustrated by the line ABCD, Fig. 2. It is that corresponding with a bias of —Y volts, Fig. 3, for which setting it will be seen that the positive peaks of V_D would carry the grid of the magnifier valve to (—150 + F) volts. The peak value of I_p would be X, which, from Fig. 2, can be seen to correspond with a peak value of V_o of Z volts. Anode current would flow during that fraction B.A.B. of the positive half cycle, C.A.C. of V_D, Fig. 3, in which the grid is more positive than —150 volts. A whole cycle of the HF. operating condition is shown on a time base in Fig. 2, and the line ABCD on the V_p I_p surface is its equivalent on that surface. The point A, which represents peak V_o and peak

I_p for that particular operating condition, falls on the line $L_1 L_2$, which, as has previously been stated, is the locus of the points of intersection of related values of peak V_o and peak I_p.

Reverting now to the transference of this locus to the $V_g I_p$ surface, Fig. 3, it is clear that it would remain a straight line, $L_1 L_2$, provided that there were no curvature of the valve characteristics. For the purpose of the argument we will assume for the moment that this is the case. That being so, it is obvious that peak I_p is proportional to variations in grid bias and therefore, also, is peak V_o.

Now, Output Power $= f_1 V_o \times f_2 I_p$, at resonance.

Where f_1 and f_2 are the ratios RMS/PEAK for V_o and I_p respectively, and under our assumed ideal conditions they will be constant ; as also will be the ratio average I_p/Peak I_p.

Therefore, Output Power$=$constant $\times$ (peak $V_o \times$ peak I_p)

Similarly, Input power $= V_B \times f_3$ peak I_p
where f_3 is the ratio average I_p/Peak I_p
$=$ constant $\times$ I_p,

and, therefore, is proportional to variations in grid bias.

$$\text{Efficiency} = \frac{\text{Output Power}}{\text{Input Power}}$$

and is thus proportional to peak V_o and therefore to variations in grid bias.

Output Power, being proportional to the product of peak V_o and peak I_p, —each of which having been shown to be proportional to variations in grid bias— is proportional to the square of these variations, and thus the aerial current is directly proportional to these variations.

If the other variables are plotted against grid bias, one obtains a very clear picture of the process, Fig. 4. Pursuing our example, input power, efficiency, output power and aerial current will all be zero when the grid bias is adjusted to -750 volts and will reach their upper practical limit at -250 volts. Input power efficiency and aerial current will appear as straight lines, whilst output power will take a square law form. If now the bias were adjusted to -500 volts and an alternating modulating voltage of peak value 250 volts superimposed upon it, the aerial current corresponding with the -500 volts, or carrier, setting would be doubled at the positive and reduced to zero at the negative peaks of the alternating voltages. In other words, the carrier aerial current of amplitude I_c would be modulated 100 per cent. linearly.

In this method of modulation the valve efficiency at maximum input, *i.e.*, at the positive peaks at full modulation of the modulating voltage, may be made equal to that for telegraphic working, by the choice of suitable values of driving voltage and grid bias. Thus it will be observed that, theoretically, for 100 per cent. modulation the aerial power in the quiescent, or carrier, condition may be one quarter of the maximum possible power of the transmitter for C.W. telegraphy, whilst the corresponding fraction for input and efficiency is one half.

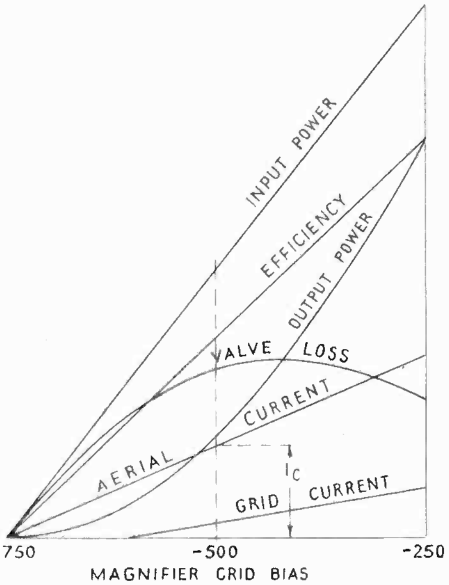

FIG. 4.

Actually, although the above statement holds in respect of the efficiency, the input and aerial power in the carrier condition must be rather less than one-half and one-quarter respectively of the C.W. telegraphy rating, if in the latter case the anode loss is the maximum that is permissible. This point is demonstrated by the curve of the Valve Loss in Fig. 4. For degrees of modulation less than 100 per cent., the carrier values of input and efficiency may be $\frac{1}{1 + M}$ of the respective C.W. ratings, and the carrier value of aerial power $\left(\frac{1}{1 + M}\right)^2$ of the C.W. rating, where M is the degree of modulation expressed as a fraction of one. Again, these fractions may be subject to slight modification on account of anode heating.

3. Distorting Effects Inherent to Magnifier Stage.

Having thus examined the basic principle of the method, the next step would be to consider the means, outlined in the introduction, which are employed in practice for varying the grid bias of a magnifier stage in sympathy with a microphone output; but before doing so it would be as well to review the causes, inherent to the magnifier stage, which make the attainment of perfect linearity impossible. In this way we shall be able to judge the relative importance of the distorting effects arising in the magnifier stage and those introduced by the mechanism employed for varying the grid bias.

Of the former the first in order of magnitude is the curvature of the magnifier valve characteristics, the effect of which is to cause the straight load excursion,

L_1 L_2 of Fig. 2, to become a curve, L_1 L_3 L_2, when transferred to the V_g I_p surface, Fig. 3. Over that portion where curvature exists peak I_p is obviously not proportional to variations in grid bias.

A second cause of distortion is that the ratios RMS/Peak and average/peak of I_p are not constant, as was assumed, over the full excursion of grid bias. The pulses of I_p are a reflection, apart from the effects of valve characteristic curvature, of that portion of the positive half cycle of the driving voltage in excess of the cut-off bias, -150 volts in our example Fig. 3. At one end of the grid bias excursion the pulse of I_p will be nearly a full half cycle of a sine-wave and at the other end will be the merest tip of a half cycle.

Both the ratios in question decrease as the grid bias is increased the result being to cause the load excursion of Fig. 2 to become curved as L_1 L_4 L_2. This, fortunately, opposes the effect of bottom curvature of the valve characteristics and tends to make it less than it otherwise would be.

A third cause of distortion is that due to the magnifier valve grid current, which constitutes a load on the source of driving voltage. When the grid bias is reduced, and the grid excursion consequently increased, this load increases and the amplitude of the driving voltage tends to fall. The result is a bending over at low values of grid bias of all the curves which are shown straight in Fig. 4. This cause of distortion can be largely overcome by providing an artificial load for the source of driving voltage sufficient to mask variations in the load due to the magnifier valve grid current.

These are the chief causes of non-linearity inherent to the magnifier stage and to illustrate their effects a set of curves plotted from actual measurements is shown in Fig. 5.

The circuits to which they apply are similar to those of Fig. 1. Two MT.12 valves in parallel working at an anode potential, V_B, of 2,500 volts were used for the magnifier stage. The driving voltage V_D, was 515 volts at zero input falling to 505 volts at maximum input due to magnifier grid current damping. Zero input occurred when the grid bias was adjusted to -705 volts, showing that the magnifier valve was "cutting-off" at $-705 + 515 = -190$ volts. Maximum input was reached with -250 volts grid bias, at which point the magnifier grid peak excursion was $-250 + 505 = +255$ volts. At -515 volts the grid bias was equal to the driving voltage and therefore the grid would just fail to go positive at the positive peaks of driving voltage.

The distorting effect of bottom curvature of the magnifier valve characteristics is shown clearly. The slight bending over at maximum input is due partly to top curvature of the characteristics, but more to the falling-off in driving voltage due to grid current damping. It will be observed that the curve of aerial current is practically straight down to one-tenth of its maximum amplitude and that it would be possible to obtain 85 per cent. sensibly linear modulation of the carrier aerial current which corresponds with a grid bias setting of —410 volts. The required swing of modulating voltage about this bias would be 160 volts. Note that on account of the falling-off in driving voltage the grid excursion would be only 150 volts for the positive half cycle of modulating voltage. The efficiency, anode output to anode input, at the setting for 85 per cent. modulation would be 42 per cent.

4. The Modulating Valve and Associated Circuits.

Having noted the causes of distortion inherent to the magnifier stage and the order of their magnitude, we can pass on now to a description of the means employed

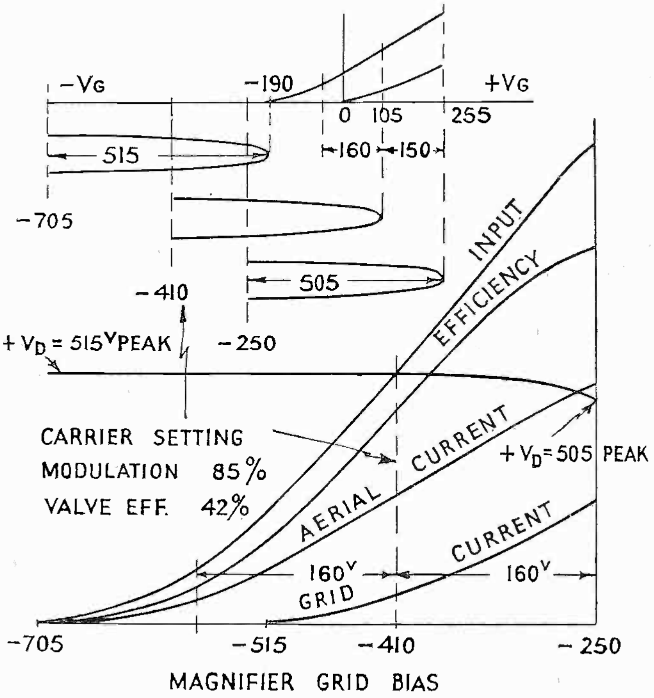

FIG. 5.

in practice for varying the grid bias of the magnifier stage in sympathy with a microphone output, and to an examination of the further causes of distortion introduced thereby.

As outlined in the introduction, the required variations in magnifier grid bias are obtained by using the anode-filament impedance of a triode to provide automatic grid bias and impressing on its grid the output from the microphone, suitably amplified, The circuit arrangements are shown in Fig. 6. It will be noticed that the filament of the modulating valve is connected to the magnifier grid and the anode to earth, for the reason that it has to pass the magnifier grid current. This fact necessitates heating the filament either with an insulated battery or with A.C. through a transformer. The latter method, which is the one shown in the diagram, is quite satisfactory and a perfect balance for hum can be obtained by adjustment of the potentiometer connected across the filament.

Similarly, the grid negative bias required for adjusting the impedance of the modulating valve tothe carrier setting must be provided by an insulated battery or by rectification from a source of supersonic frequency. The latter alternative is illustrated in the diagram, which indicates a way of obtaining the required negative bias by rectification of H.F. voltage derived from the stage prior to the modulated magnifier. The rectifier for this purpose may be a small receiving valve, since the power taken is negligible, and no undesirable hum is introduced by heating its filament with A.C., as for the modulator valve.

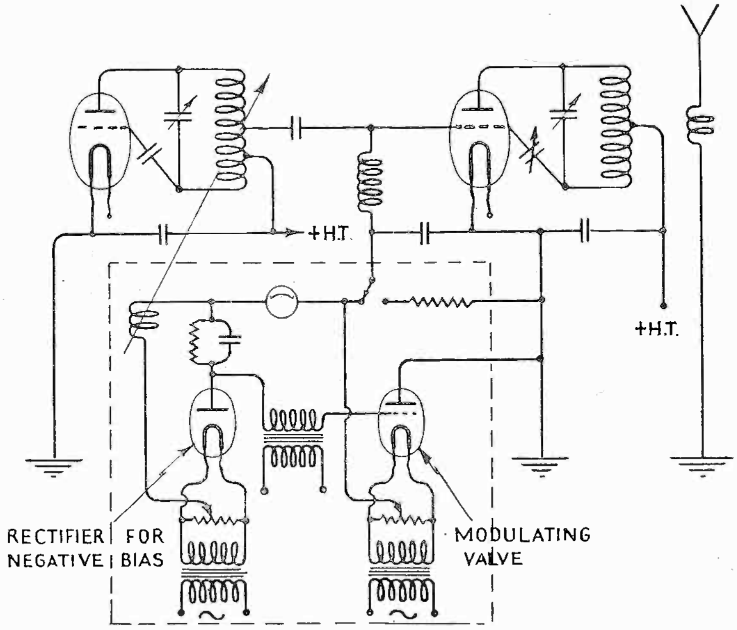

FIG. 6.

The above way of obtaining negative bias for the modulating valve results in a reduction of the distortion due to bottom curvature, for the following reason. At low magnifier input values, where bottom curvature occurs, grid current is small or zero and the H.F. current in the prior stage rises, because it is relieved of the grid current damping. This in turn results in increased negative bias on the modulating valve grid, thus artificially increasing the amplitude of the negative swings of modulating voltage.

An H.F. choke must be connected between the magnifier grid and the modulator filament, as otherwise the resistive high capacity paths to "earth" from batteries, transformers, etc., will give rise to a serious load on the source of driving voltage.

The only other apparatus required is a line to grid or microphone to grid transformer, as the case may be, and some means of checking the amplitude of the modulating voltage set-up across the transformer secondary.

A point which has to be considered in design is that all apparatus connected to the filament of the modulator valve is negative to earth by the amount of the magnifier valve grid bias. Insulation must be provided, therefore, to withstand the maximum value of this grid bias voltage, namely, that occurring at the negative peaks of the modulating voltage.

The modulating valve needs only to be very small compared with the magnifier valve, since it has to deal only with the watts represented by the power taken by the magnifier valve grid leak at the carrier setting. For instance, one L.S.5 valve is able, comfortably, to act as a modulating valve for a magnifier stage consisting of two M.T.12 valves in parallel working at a carrier input of 400 watts, anode potential 3,000 volts. It must have a total emission capable of handling the peak value of the magnifier grid current which flows at the positive peaks of modulating voltage at full modulation, and it must be equal to withstanding the value of magnifier grid bias voltage corresponding with the negative peaks of modulating voltage. It must have an impedance such that with a small negative bias, sufficient only to ensure the absence of grid current, the maximum rating of the magnifier stage may be obtained efficiently; the small negative bias referred to being the difference between the positive peaks of modulating voltage set-up across the grid transformer secondary and the negative bias value for the carrier setting. Finally, its anode characteristics should be as linear as possible down to $I_p = O$.

5. Limitation of Depth of Modulation and Distortion introduced by Modulating Valve.

The method just described for obtaining the required variations in the magnifier stage grid bias lends itself readily to static measurements of the depth and linearity of modulation, since the alternating modulating voltage may be simulated statically by varying the modulating valve negative bias. The simplicity of the method is self-evident, but unfortunately, for two reasons, it reduces considerably the percentage of linear modulaton we have seen to be attainable even when the variations in magnifier grid bias are proportional to the modulating voltage.

(A) It imposes a limit to the excursion of magnifier grid bias.

(B) The relationship between variations in modulating valve negative bias and the magnifier stage grid bias is far from linear.

Taking these two effects in the order given, it is obvious that the greatest possible value of magnifier grid bias obtainable is that corresponding to the value of negative bias sufficient to "cut-off" the modulating valve. Under that condition the magnifier valve will, in effect, be working with an open grid, and the grid leak condenser will charge up and bias back the magnifier grid to the point where the positive peaks of driving voltage just fail to produce grid current, at which point the charging up process will, of course, cease. Increasing the modulating valve negative bias beyond the cut-off value will not effect any further decrease in input, efficiency or aerial current.

Fig. 7 illustrates the effect on the possible depth of modulation of this limitation. X and Y represent the load excursions on the V_g I_p surface for two magnifier valves of different characteristics. The maximum magnifier grid bias obtainable from the modulating valve will be M volts, such that the positive peaks of the driving voltage V_D just fail to produce grid current.

The greatest possible depth of modulation for X would be A/B of a carrier of amplitude B, *i.e.*, about 50 per cent. as drawn.

On the other hand, in the case of Y, zero input and zero grid current coincide and therefore, disregarding non-linearity, it would be possible to obtain 100 per cent. modulation of a carrier of amplitude C.

TABLE 1.

Magnifier Valve	*m.*	V_B.	% Modulation
MT. 9	90	4,000	90
MT. 7a	80	3,000	90
MT. 5	40	1,500	90
MT. 9	90	6,000	85
MT. 7a	80	10,000	75
MT. 12	20	2,500	75
DET. 1	11	1,000	35
MT. 12	20	8,500	28

The extent of this limitation in any particular case is clearly a function of the magnification factor of the magnifier valve and the anode potential, V_B. Some representative examples are given in Table 1. The percentage modulation shown is the maximum obtainable disregarding non-linearity.

This limitation is a very definite disadvantage of Direct Current Grid Modulation, since it restricts the designer in his choice of magnifier valves and anode potential.

Coming now to the distortion introduced by the modulating valve, the two chief causes of such distortion are bottom curvature of the magnifier valve grid characteristics and bottom curvature of the modulating valve anode characteristics.

These effects are best understood by examination of the V_g I_p characteristics of the modulating valve. Fig. 8 gives these characteristics for an L.S.5 valve, and the curve marked Mag I_G — Mod. I_p drawn thereon is the grid current of a magnifier stage consisting of two M.T.12 valves with an L.S.5 as the modulating valve. The circuits used were as shown in Fig. 6, and the curve was obtained statically by varying in steps the negative bias of the modulating valve.

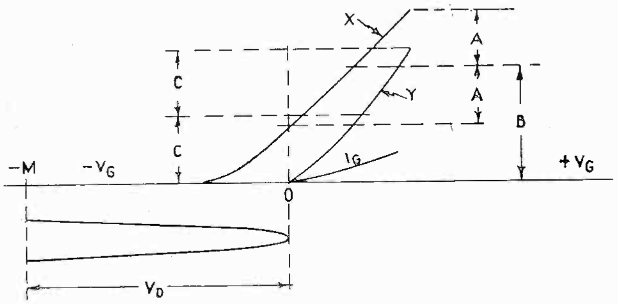

FIG. 7.

The grid current of the magnifier stage, since it flows through the modulating valve, is naturally the anode current of the latter. Therefore, the potential which existed between its filament and anode for any particular setting of the negative bias may be read-off from the intersection of the grid current curve and the modulating valve anode characteristics.

The result is the curve markėd Mag G.B. — Mod. V_p, the potential between filament and anode of the modulating valve being obviously identical with the grid bias of the magnifier valves.

It will be observed that the result of bottom curvature of the magnifier grid current and of the modulating valve characteristics is a considerable departure from linearity in the relationship between modulating valve negative bias and magnifier valve grid bias variations.

Thus, the departure from true linearity inherent to the magnifier stage, as illustrated in Fig. 5, is increased to the extent indicated in Fig. 8.

Since, input, efficiency and aerial current all increase as magnifier grid bias is decreased, one would expect to find the curves of these variables, when plotted against modulating valve negative bias, to be an inverted reflection of the curve of magnifier grid bias in Fig. 8, plus an additional curvature due to the inherent non-linearity of the magnifier stage.

Fig. 9 shows a set of curves taken from actual measurements. The magnifier stage was again two M.T.12 valves in parallel, working at an anode potential of 2,500 volts. The modulating valve was one L.S.5. The amplitude of the positive peaks of the driving voltage, V_D, was 525 volts falling to 515 volts at maximum input due to magnifier grid current damping of the source of driving voltage. Note that the curves of input, efficiency and aerial current become parallel to the base line just beyond the point where grid current starts, for the reason given in the first half of this section. It will be seen that the greatest depth of sensibly linear modulation obtainable would be 63 per cent. of the carrier aerial current which corresponds with a setting of −45 volts bias on the modulating valve. The peak amplitude of the modulating voltage required to give full modulation would be 45 volts, measured across the secondary of the grid transformer. The efficiency at this carrier setting would be 49 per cent. anode output to anode input.

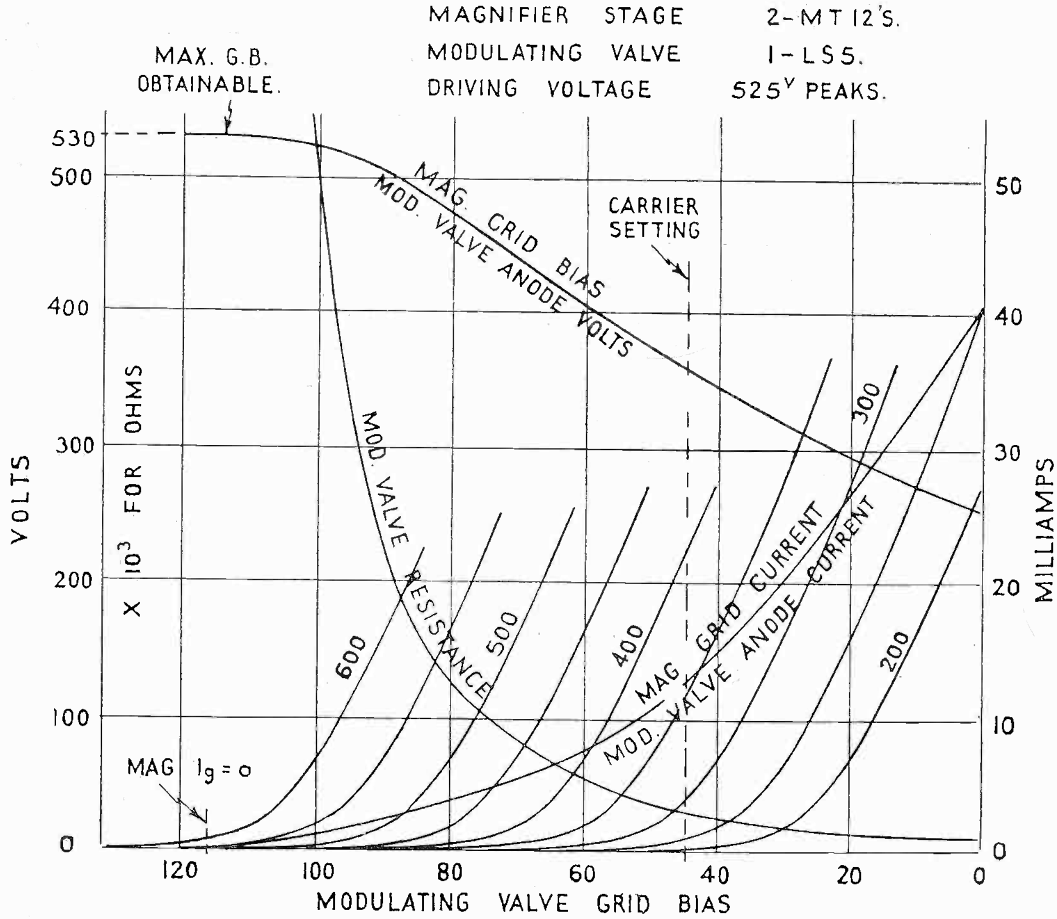

FIG 8.

The above may be taken as an average example of the depth of modulation and degree of linearity attainable by this method of modulation with the transmitting valves in general use in the Marconi Company, when working at their normal rated anode potential.

The depth of modulation could be increased to a little over 70 per cent. for the example in question, with a consequently somewhat reduced carrier power if no more than good commercial quality speech were required.

6. Comparison with other Methods of Modulation.

On the score of the depth and linearity of modulation attainable, both the choke Control and Power Amplifier methods are superior to the Direct Current Grid Method.

With Choke Control it is possible, by using a higher voltage for the modulator than for the oscillator valve, to obtain 100 per cent. modulation with almost perfect linearity.

The Power Amplifier method originates its modulation in a Choke Controlled stage, the modulated output of which is impressed on the grid of a magnifier stage having a fixed bias, this constituting the difference between it and the Direct Current Grid Method, in which the driving voltage is fixed and the bias modulated.

In the Power Amplifier Method the percentage modulation attainable obviously depends only on the percentage modulation of the choke controlled stage; whilst the degree of linearity depends on the linearity of the choke controlled stage, on the straightness of the magnifier valve anode characteristics and on the value of magnifier valve efficiency demanded. Power Amplifiers are in operation, adjusted for 100 per cent. modulation, linear within the definition of linearity agreed upon internationally, and having a magnifier valve efficiency of 32 per cent.

Mod. dep
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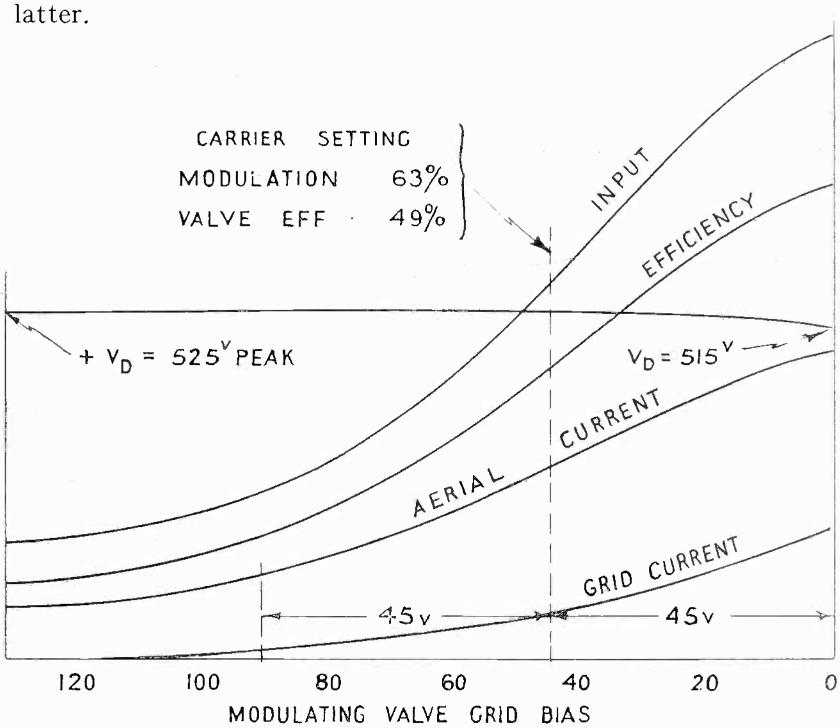
In the Direct Current Grid Method, as has been shown, 100 per cent. modulation would be only attainable if the characteristics of the magnifier valve were such that anode and grid current cut-off simultaneously at the anode voltage employed. One hundred per cent. modulation with this method must of necessity imply grave non-linearity, since as shown on page 14, in order that the aerial current may be reduced to zero at the negative peaks of modulating voltage the positive peaks of driving voltage must withdraw beyond the cut-off point of the magnifier anode feed, with consequent serious effects due to bottom curvature of the magnifier anode characteristics. In addition, there is the distortion introduced by the modulating valve.

It would appear, therefore, that the Direct Current Grid Method of modulation cannot provide the depth of linear modulation demanded by present day broadcasting standards, as can both the Choke Control and Power Amplifier Methods.

Coming now to the question of total anode power required for equal modulated power in the aerial, there is no great difference between one method and another; whether the magnifier valves are worked at C.W. telegraphy efficiency and anode modulation provided by valves taking power comparable with that taken by the magnifiers, or whether they are worked at the low efficiency involved by an adjustment which renders them capable of magnifying linearly a modulated grid input. What difference exists favours the Direct Current Grid Method, since in that method no power is required for modulating the magnifier grid input.

In matters of filament power, and bulk and cost of apparatus required, there are, however, greater differences, the greatest discrepancy in these respects lying between the Choke Control and Direct Current Grid Methods, the advantage being with the latter.



Magnifier Stage 2-*MT*12*'s* *Aerial Carrier Power* 175 *Watts.*
Modulating Valve 1-*LS*5 *Anode Volts* 2500

FIG. 9.

To illustrate the extent of the advantage Table 2 gives the principle data for a Choke and Grid controlled transmitter.

The example is of a transmitter having one M.T.7A as the final magnifier. The C.W. input rating is taken as being V_p = 8,000 volts, I_p = 325 m/a, 2,600 watts. It has been assumed that at the C.W. rating the H.F. circuits have no more than the proper factor of safety and that for Choke Control the anode volts must be lowered to the point at which under full modulation they will not exceed 8,000 volts. Similarly, the feed must be lowered in the same proportion as otherwise the filament will limit unless overheated.

The driving stages are omitted from the table since they are unaffected by the choice of modulation method. It should be noted, however, in this connection, that Grid Control could not be employed if the transmitter were a Self-Oscillator.

TABLE 2.

	Grid Control.	Choke Control.
Magnifier Valve	1-MT. 7a	1-MT. 7a
,, ,, Filament Watts	300	300
Modulator Valve	1-DET. 1	1-MT. 9a
,, ,, Filament Watts	12	145
Sub-Modulator Valve	—	1-MT. 4b
,, ,, Filament Watts	—	80
Total Filament Watts	312	525
Anode Volts	8,000	5,000
,, ,, Full Modulation Peak	8,000	7,850
Anode Feed —Magnifier m/a	185	200
,, ,, Modulator m/a	—	200
Speech Choke	—	To carry 400 m/a
Magnifier Anode Input—Watts	1,500	1,000
Total ,, ,, — ,,	1,500	2,000
Aerial Carrier Power—Watts	560	650
Mag. Anode Input/Aerial Carrier Power	37%	65%
Percentage Modulation	75%	57%

For general purpose transmitters, Naval, Military, etc., in which space and ease of changing from C.W. to telephony or I.C.W. are more important than the attainment of perfect reproduction, the Direct Current Grid Method has great advantages over any other, since not only is the additional apparatus required for modulation purposes far less for Grid than for Choke Control, as can be seen from Table 2, but, in addition, Grid Control makes possible an extremely simple change-over from C.W. to Telephony.

Referring to Fig. 6, it will be seen that the low potential end of the grid choke is taken to the common point of a two-way switch. One side of the switch is connected to the filament of the modulating valve, and the other to a grid leak resistance of suitable value for the C.W. adjustment of the magnifier. The switch can be provided with additional contacts to switch-on the heating for the modulating and grid negative rectifier valves, and to close the microphone circuit. A third position can be provided for starting-up a buzzer, or audio-frequency oscillator, and connecting it to the primary of the grid transformer for I.C.W. transmission. The whole of this apparatus is at low potential and may be mounted as a separate unit in any convenient part of a ship's cabin or army lorry.

For installations of this nature a sensitive galvanometer in the grid circuit of the modulating valve serves as a satisfactory level indicator of the modulating voltage, since the presence of grid current indicates that the peak amplitude of the modulating voltage is equal to the negative bias and that, therefore, the transmitter is fully modulated.

F. C. LUNNON.

MARCONI NEWS AND NOTES

MARINE WIRELESS TELEPHONY.

WHITE STAR LINER "HOMERIC" EQUIPPED WITH MARCHESE MARCONI'S NEW APPARATUS.

"Homeric" Telephone Receiver.

THE first ship fitted for commercial operation with the new short-wave marine telephone apparatus developed by Marchese Marconi is the White Star Liner "Homeric." Marchese Marconi's successful experiments with this type of equipment on his yacht "Elettra," were described in THE MARCONI REVIEW, Nos. 19 and 20.

The British Post Office announced on May 29th the opening of a regular telephone service from the "Homeric" to Great Britain and the United States of America, following a series of tests between the ship in Mid-Atlantic and the authorities on each side. The service has now been extended to include France, Switzerland, and other countries.

During the tests conversations which took place between England and the "Homeric" over distances of more than 2,000 miles and also between the liner and New York were reported by officials to be **the best in clearness and quality ever heard from a ship on the Atlantic.** These experts, in fact, expressed themselves as amazed at the results achieved.

On May 28th officers on board the "Homeric" rang up the White Star Line offices in London and were able to discuss easily the progress of the voyage and to compare the state of the weather 1,200 miles out in the Atlantic with that in London.

Telephone conversations also took place between representatives of the Marconi Company at Marconi House, London, and officers on the "Homeric," congratulations being sent to the wireless engineers and operators on board upon their success with the new Marconi apparatus fitted for the first time for commercial operation.

Demonstration of Remarkable Quality.

The remarkable quality of the telephone service available through this installation was demonstrated to thousands of wireless listeners in the British Isles on Friday evening, June 6th, when a conversation between a passenger on the "Homeric," 1,000 miles out from Southampton and Mr. Harold Nicolson, in the B.B.C. studios at Savoy Hill, London, was broadcast by the British Broadcasting Corporation. Every word of the passenger's description of the sea scene before him and of the day's happenings on board was as clearly heard as the questions and comments of Mr. Nicolson speaking into the microphone in London. Particularly noticeable was the clarity of the speech from mid-Atlantic and the absence of "background," that annoying hum or crackling which sometimes ruins long-distance telephony even by land-line.

Organisation of the Service.

The shore end of the service in Great Britian is carried out by the Post Office, the Rugby wireless station being used for transmission to the "Homeric," and the Baldock station in Hertfordshire for reception from the ship. These stations are connected by landlines with the London Trunk Exchange where the service is controlled.

On board the "Homeric," a special extension of the Marconi cabin has been erected to house the telephone equipment, close to the telephone room from which passengers speak to their friends ashore. The telephone installation operates on wavelengths of about 24 and 70 metres, with a power of 2 kilowatts in the aerial.

With a telephone transmitter of this type Marchese Marconi has carried on wireless telephone conversations from the S.Y. "Elettra" in the Mediterranean, with Sydney, London, Montreal, Bombay, Cape Town, New York, Buenos Aires, and Rio de Janeiro. On April 30th he was "interviewed" on board the "Elettra" by a journalist who was in New York, 4,400 miles away, and the interview was re-broadcast throughout the United States.

With this apparatus therefore the telephone service from the "Homeric" and any other ships similarly equipped will be capable of a very wide range, making it possible, if required in the future, to link up with the shore telephone circuits in many countries and at almost any distance.

The charge for the ship-to-shore telephone service is £4 10s. od. for the first three minutes and £1 10s. od. for each additional minute to Great Britain and the United States.

Tenth Anniversary of Dame Melba's First Broadcast.

June 15th was an historic date in the development of broadcasting. It was on this date ten years ago that Dame Melba broadcast her memorable concert from the Marconi Company's experimental station at Chelmsford. The occasion was the first on which an artist of international reputation had sung before the microphone, and was virtually the birth of entertainment broadcasting in Great Britain.

Next day there arrived from most European countries telegrams containing expressions of wonder and appreciation. At Oslo the signals were so strong that the operator at the wireless station, some distance from the town, relayed the music by telephone to the principal newspaper offices.

Following the great public interest aroused by Dame Melba's concert, the famous Marconi experimental station at Writtle was established in 1921 to give occasional broadcasts for an ever-increasing number of listeners. The first 2LO, installed at Marconi House, London, made its appearance on the ether early in 1922 as a supplementary experimental station to Writtle.

With the evolution of broadcasting from the experimental stage of ten years ago to the great public service it is to-day, the Marconi Works at Chelmsford has maintained its importance as a centre of pioneer work. It is the site to-day of G5SW, the world-wide short-wave broadcasting station, and was the first home of 5XX before its removal to Daventry.

Death of Mr. Jack Cave.

It was with much regret that the Marconi Company received the news of the death on the 14th inst., of Mr. Jack Cave, one of their earliest pioneers.

Mr. Cave was in his 58th year and had been ill for several weeks.

His special knowledge of the technique of glass blowing and his skill as a master instrument maker led to his appointment in 1897 to the personal research staff of Mr. Marconi, whom he assisted in the construction of much of the early apparatus.

He was thus the first mechanic to be associated with the commercial development of wireless telegraphy, and under him the art of coherer manufacture and testing reached a high degree of precision and performance.

He began his work at Bournemouth, it was continued at Poole, and in 1899 commercial manufacture was begun at Chelmsford. With the advent of the magnetic detector superseding the coherer, Mr. Cave's wide practical knowledge led to his appointment in 1907 as Foreman of the Machine Shop and he retained this position in the new Works which were opened in 1912. In 1922 he was appointed Chief Rate Fixer which position he held at the time of his death.

He was highly esteemed by all who knew him. He was greatly interested in sport especially running and boxing and was one of the Founders, and a Vice-President, of the Marconi Athletic and Social Club.

Mr. Cave leaves a widow and two sons.