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MARCONI DIRECTION FINDER
TYPE D.F.G.9c

This article discusses the problems and experimental results leading to the design of Direction Finder, Type D.F.G.9c, which the Marconi Company now confidently offers for submarine installation.

DURING the past few years radio direction finding has made almost incredible progress in establishing its claim as a reliable aid to marine navigation, and its inclusion in the standard equipment of naval and mercantile vessels is now practically universal. A notable exception, however, is the submarine, which, by virtue of its peculiar structure and habits, has from time to time rejected as unserviceable the several conventional forms of D.F. apparatus.

Nevertheless, the hazards of submarine operation have always made conspicuous appeal for the provision of adequate means for direction and position finding, not only whilst cruising on the surface, but also when navigating submerged.

To this important demand the Marconi Company has been fully alive for a considerable time, and after combined research and experimental work with generous assistance from the British Admiralty, has evolved a type of Direction Finder installation which meets submarine conditions magnificently.

In addition to describing the equipment known as D.F.G.9c, it is proposed here to outline how this attractive engineering problem has been attacked and with what results.

Frankly, at the outset, the obstacles to absolute success seemed formidable, as little or nothing was known as a reliable basis for design. There were, of course, instances of D.F. apparatus installed on submarines for surface working, and further it was known that long wave signals could be read a few feet below the surface of the sea. These elementary facts, however, were far removed from the realisation of a comprehensive Direction Finder appropriate to service conditions and capable of results comparable with those normally expected in other branches of marine practice.

When a Master Mariner on the high seas has to determine his position out of a maze of uncertainties he skilfully arrives at his result by a process of scientific guessing known as "dead reckoning," and this particular art has its counterpart in abstract engineering problems such as the one under review. Science has been aptly described as applied common sense and never was this more strikingly evidenced than in the case of tackling the submarine D.F. problem which presented itself for consideration under six principal headings :—

1. Decision as to the system to be employed (whether rotating frame or Bellini-Tosi).
2. Structural mechanics relating to aerial design.

3. Aerial insulation.
4. Receiver and amplifier design.
5. Provision for "sense" finding when operating submerged.
6. All the above in respect to the limits of space accommodation.

There was little difficulty in arriving at a decision to use a Bellini-Tosi system. Rotating frames are not easily adaptable to remote operation and have nothing to offset this disability against modern B/T improvements. Further, the idea of manipulating a rotating aerial below the surface of the water with the vessel proceeding at 7 or 8 knots was practically out of the question.

Probably the most important of all considerations was that relating to aerial mechanics. Clearly, the design and method of installation must in no way interfere with the safety or stability of the vessel, and further, to the smallest detail, must be subject to Admiralty approval.

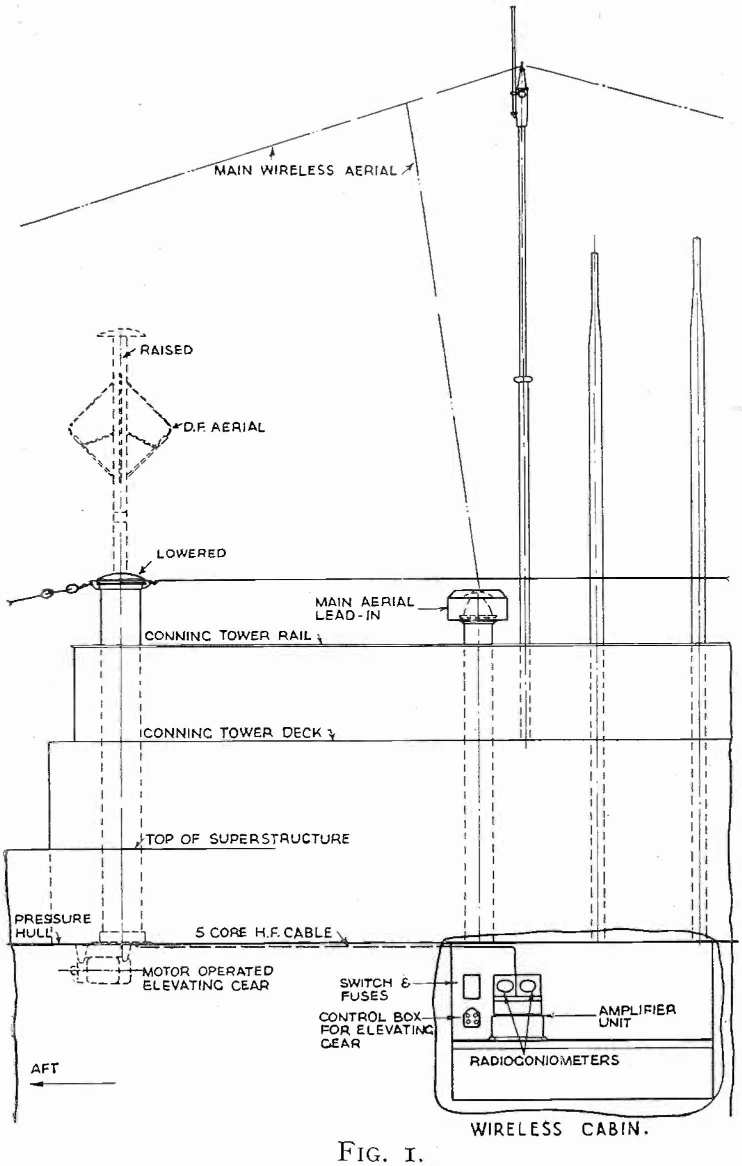

FIG. 1.

Fig. 1 shows a general arrangement of the aerial mast and associated equipment in the submarine. The mast has an extended height of 23 feet 6 inches. This fundamental feature allows the active receptive areas to be raised at will to an advantageous elevation in respect to the submarine's recorded depth of submersion.

Further, by supporting the loops well clear of the hull, it ensures a low value of quadrantal error and therefore, as will be shown later, facilitates calibration. When not required for use the loops may be closed and brought down into the lower section or outer casing of the mast structure. This telescopic action is controlled by an electric hoist and reversing gear which is capable of raising or lowering the aerials to full extent in approximately 30 seconds.

It might be wondered that hydraulics were not to be preferred for aerial manipulation, more particularly since an ample source of power is usually available in submarines. The principal reason for discarding hydraulics, however, was that, by virtue of telescopic action, the loop feeders must fall into a bight and be housed for protection by the outer casing of the structure itself. With hydraulic rams this was considered to be impracticable.

The aerial loops, which are unscreened, are formed by two lengths of 5-core cable of Admiralty pattern. At the lower apex of each " diamond " the four ends pass through pressure tight glands into a junction box where the conductors are connected in series to form two coils of a normal B/T system. From the junction box the two extremes of each coil are connected by a length of similar cable in its own part directly to the receiver. The odd, or fifth core, is used to connect the metal supports of the frame to the screens of the amplifier, thereby avoiding (between extremities of the system as a whole) varying differences of potential which otherwise would produce a spurious reception diagram.

Although well known in dockyard practice, an interesting feature is the method of passing the vulcanised rubber cable through the pressure hull of the submarine. In order to provide a sufficiently incompressible surface to take the strain of a compression gland, the appropriate region of the cable is protected by a length of slightly oversize copper tube. The tube is then reduced in diameter towards each end by means of a blank die which makes effective seals against water ingress. The cable thus reinforced is then " packed " into a gland and pulled up dead tight. A second gland accommodates the spindle on to which is keyed the driving pinion for the frame hoist and these are the only two fittings for which it is necessary to drill the pressure hull.

The problem of frame aerial insulation as applied to marine work generally is one of long standing, but is much more acute and of greater importance in the case of submarine installation. It is an unfortunate fact that all the known insulating substances will, under provocation, either break, split, perish, absorb moisture or exhibit a hundred and one other disagreeable properties, any of which may represent a dividing line between successful underwater direction reception and the reverse. It was therefore imperative to use in the frame structure the minimum amount of insulating material. Ultimately this has been reduced to the vulcanised coverings of the aerial conductors which are of a particularly tough and pressure-tight variety. The difficulties of aerial insulation are self-evident from the fact that many ordinary grades of " laid " cable will admit water freely and short circuit adjacent conductors at quite ordinary cruising depths.

The receiver Type D.F.G.9c, covers the conventional waverange of 350—4,000 metres, but differs from standard models in one or two important details of design, both electrical and mechanical. The electrical changes relate in particular to the aerial input, calibration and " sense " circuits, whilst mechanical modifications have been necessitated to facilitate installations and operation in confined spaces. Surface conditions call principally for medium wave operation, whilst wavelengths of 2,000—4,000 metres are more useful when operating submerged. From a D.F. standpoint these are extreme conditions which have called for careful compromise in design.

In the first place the key to frame reception is represented by

$$\frac{2\pi nA}{\lambda}$$

So that with nA (area turns) constant over the waverange of the receiver, the effective height of the aerial is inversely proportional to the received wavelength. When working submerged, signal loss due to attenuation is, of course, very much in favour of the higher wavelengths, but in view of the equal importance of upper and lower wavebands in submarine work, a fundamental problem existed in maintaining a signal strength level between extremes of the tuning scale. Clearly it was desirable to provide a multiplicity of transformation ratios between frame and receiver—each ratio being appropriate to a given waverange. It was determined experimentally that two ratios were sufficient to produce the desired result over the waverange 350—4,000 metres. This, however, implied two separate and complete radiogoniometers, so that mechanical interpretation was of considerable importance in order to avoid adding complexity and bulk to the apparatus or detracting from the quick search features of the system.

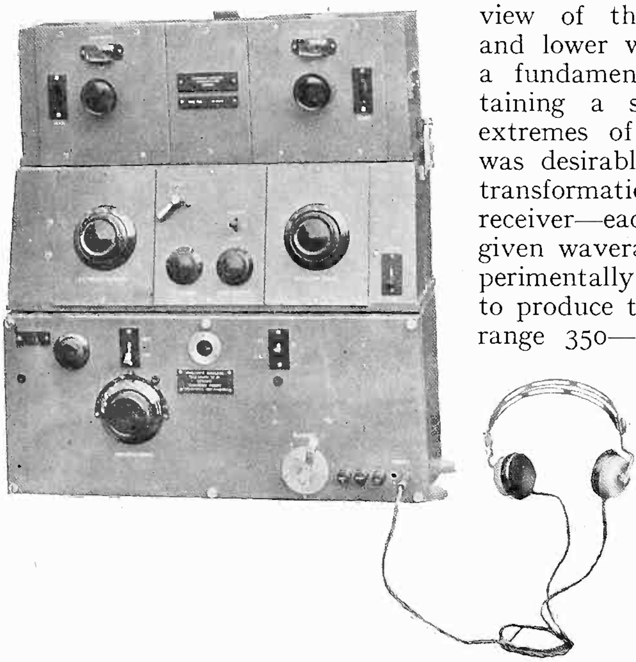

FIG. 2.

In the second place quadrantal deviation due to the disparity in earth conductivity between the two perpendicular directions of the hull has different peak values according to the conditions of operation. Quadrantal correction therefore becomes a multiple process and this has been simply catered for in the radiogoniometer unit in such a way that correct "relative" bearings may be read directly from the scale for any wavelength, whether on the surface or submerged.

Thirdly, the addition of a circular polar to the frame diagram for the purpose of sense determination is a vastly different proposition under water from that obtaining on the surface. Once submerged, the effective height of a plain aerial (unless of extravagant design) loses all relationship to its linear proportions, whilst with a frame the only important signal loss is that due to attenuation. Any combination of aerials, therefore, adjusted for cardioid balance under normal conditions is quite useless below the surface of the water. Practical considerations, too, prohibit the use of supplementary aerials in connection with submarine equipment so that it has become vitally necessary to look to the frame as a self-contained

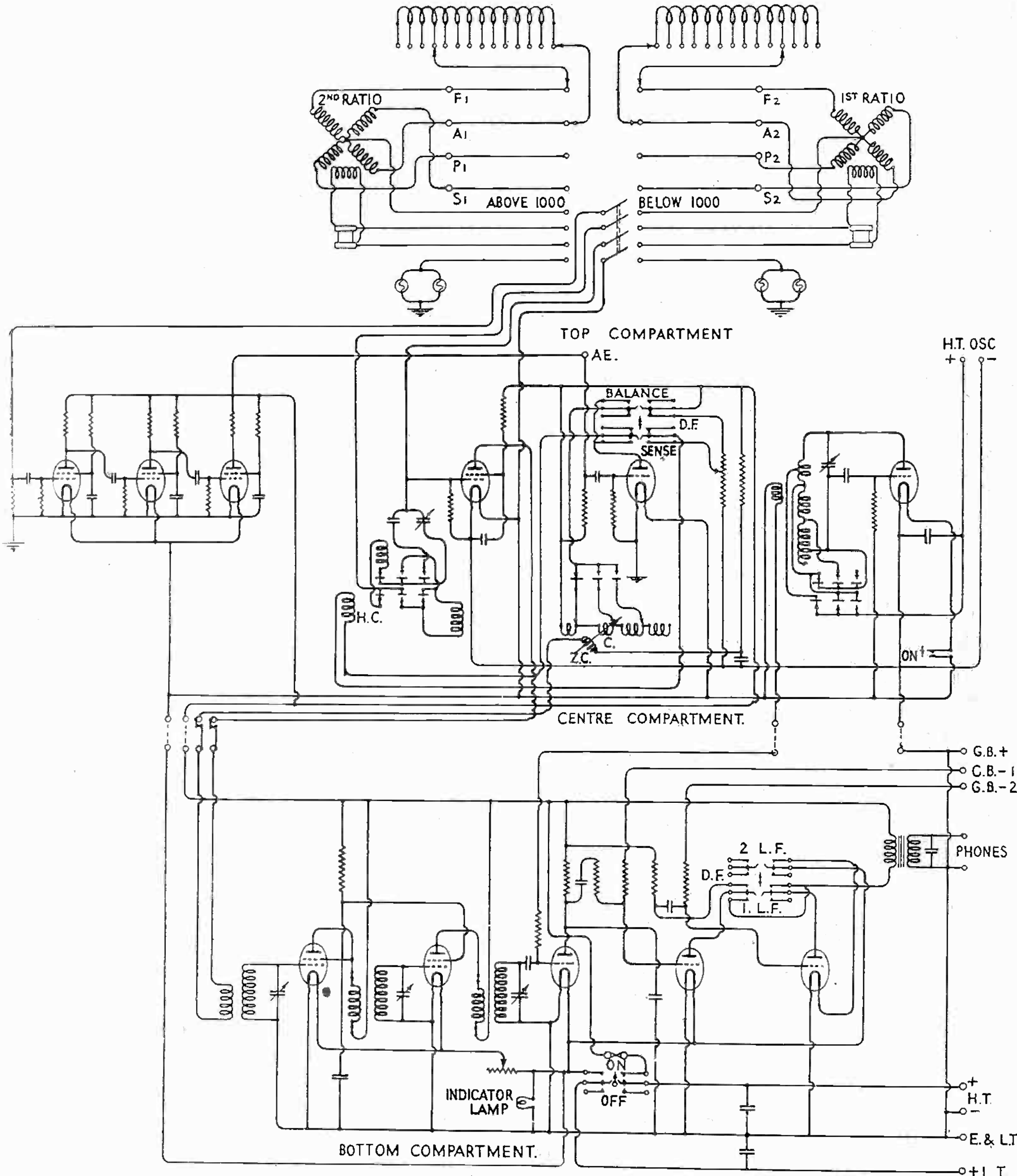

FIG. 3.

device appropriate to all its functions. Accordingly, the loops themselves are arranged to function additionally as a vertical aerial supplemented by sufficient control of amplification to bridge the wide gulf between surfacing and diving requirements. Actually, when using the " sense " or " stand-by " positions of the instrument, seven stages of high frequency amplification are available—three of which are tuned.

Fig. 2 gives a photographic illustration of the instrument which has an overall height of 2 feet 6 inches and occupies a bench space of 2 feet by 10½ inches. The latter dimension (front to back) is the most important to meet space accommodation of the order usually available in submarines. An invaluable feature is the ease with which the top, centre, and bottom sections can be detached one from the other to permit passage through hatchways and so forth. With reference to the Figure in the left hand and right hand top compartments are housed separate goniometers, each having a transformation ratio suited to the waverange indicated. By means of the switch shown at the extreme top of the figure, either secondary (search coil) may be tuned by the condenser in the left hand middle compartment. The switch which also changes over the source of illumination from one scale to the other, is controlled by a spring loaded flap which covers, or closes, the set of aerial input sockets for which the circuits of the receiver are not appropriate and therefore only the scale which is illuminated can be read. Each gonio scale is attached to and rotates with its search coil spindle and to facilitate reciprocal readings the scales are doubly engraved, i.e., each character is shown against its 180 degrees reciprocal. For D.F. observations both sets of figures may be read against a cursor through a lens which magnifies the scale over about 30 degrees of arc. For " sense " readings, the scale in use is rotated through 90 degrees in either direction and observed through a coloured aperture of such width that only one of the two sets of engraved figures may be read, and ambiguity of 180 degrees is avoided in this way. If for any reason it is desired to reverse the indicated direction of " sense," all that is necessary is to slide the " sense " window laterally so as to reveal the inner instead of the outer scale (or vice versa) and to secure in the desired position. The small lamps for lighting the various compartments of the instrument are carried by detachable plates and can be removed or replaced without the disconnection of leads. The centre top compartment contains the calibration chokes for both goniometers. These are left in permanent adjustment in response to the switch mentioned above. In the bottom compartment and the right hand centre compartment are the main amplifier and oscillator respectively, whilst the centre compartment of the middle section carries the circuit arrangement for sharpening scale definition at the point of zero signal. Here also is positioned the amplification control in connection with the vertical aerial and " sense " finder. The complete theoretical diagram is given in Fig. 3.

This type of installation already carries the distinction of considerable service at sea under typical submarine conditions. Seaworthiness and reliability are therefore now established and the following summarised particulars are interesting from the point of view of practical handling.

For surface working the D.F.G.9c is a perfectly straightforward proposition of high accuracy and with a range of reception exceeding that usually associated with small frame Direction Finders. Normally, however, " hull effect " is rather pronounced and the application of " zero clearing " is desirable for first class bearings.

With regard to calibration the advantage of high frame elevation is evidenced by curves A and B of Fig. 4. These represent the result of tests for which the correction circuits of the instrument were disconnected and show, after correction for index errors, that quadrantal deviation is practically the same for signals differing widely in frequency. This is convenient in permitting a common choke adjustment suitable for all wavelengths when surfacing and the curve representing the correction required in this case is shown by D (Fig. 4).

Considerations of consistent accuracy make it necessary to ensure that the quadrantal error curve which it is desired to correct represents the longitudinal effect of the vessel only. Clearly if this is irregularly augmented by linear conductors such as obstruction wires, aerials, etc., which tend to respond to frequencies related to those over which the instrument is designed to operate errors will appear of varying magnitude according to the wavelength in use.

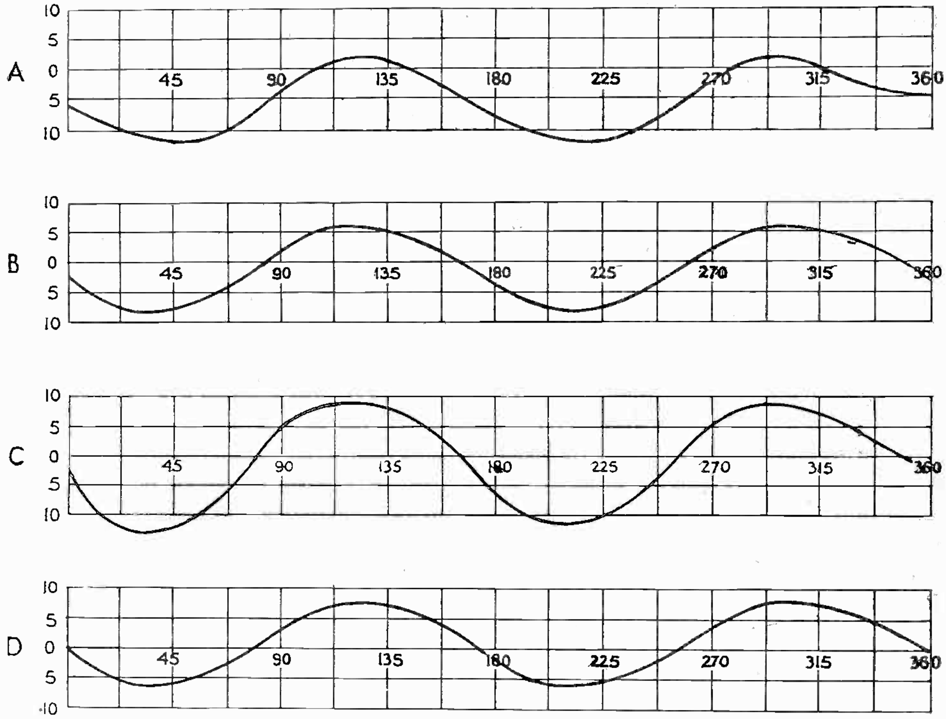

Fig. 4.

Fig. 4 (C) is the actual result of D.F. observations on a frequency approaching the natural response of a "diving" aerial when the true curve for the vessel was that represented by "B." Still closer to resonance the quadrantal peaks would become fantastic and graphical representation impracticable. It is therefore imperative to legislate for all extraneous aerials to be isolated and under control during D.F. operation.

The following comparative details relate to operation conditions below the surface. It is now fairly clear that the fundamental basis of successful underwater reception is a well designed frame aerial which is capable of adjusting its active areas to a favourable elevation in respect to registered depth. It is important to note that aerial circuit resonance does not change on submersion and further that a remarkable improvement in the reception diagram takes place. Zeros become perfectly sharp for all parts of the scale so that the application of semicircular correction is quite unnecessary. Also, resulting from greater uniformity in earth conductivity, quadrantal error is greatly diminished—it is never zero—but the method of determining its value has to be very different from that adopted on the surface. Under the latter condition the usual procedure is simultaneously to take visual and direction finder observations of a distant transmitter over a sufficient number of points and to plot the resulting differences in the conventional manner. Under water, however, the relativity between transmitter and receiver is not known—in fact the only reliable asset is the direction of the ship's head (true) by gyro. It is nevertheless quite easy to effect calibration as shown by the following example. All that is necessary is to take two bearings of the same station (in fairly quick succession) on two different courses in the same half-quadrant. Obviously, if the quadrantal error is zero both observations will agree, but supposing the following differences to occur :—

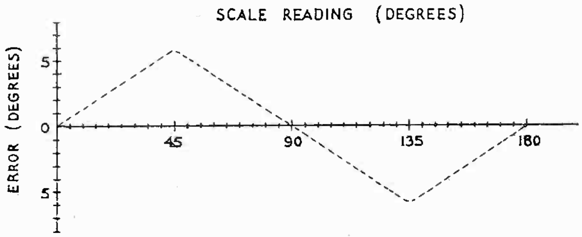

Fig. 5.

			Deg.
(1)	True Course	.. ..	270
	Relative Bearing	..	17
	True Bearing..	..	287

			Deg.
(2)	True Course	.. ..	255
	Relative Bearing	..	34
	True Bearing..	..	289

This will indicate that in 15 degrees the D.F. error is "plus" 2. Assuming "index" errors to have been cleared by surface tests, a curve can be interpolated on the known conditions, Fig. 5, from which it is seen that the two previous readings should have been :—

(1)	True Course	.. ..	270
	Relative Bearing	..	$14\frac{1}{2}$
	True Bearing	..	$284\frac{1}{2}$

(2)	True Course	.. ..	255
	Relative Bearing	..	$29\frac{1}{2}$
	True Bearing..	..	$284\frac{1}{2}$

This method, if carefully done, is quite positive, whilst if the process is repeated with agreement in each of the four quadrants the result is infallible.

Conditions governing underwater performance generally are so numerous that it is difficult at present to give comprehensive information regarding range of reception. Instances from recent records show that Daventry's programme on 1,500 metres can be received at good strength at a registered depth of 30 feet when the field strength at the surface of the water is of the order of 6 millivolts per metre. Also that reliable bearings can be obtained using an "arc of silence" of 30 degrees. By heterodyning the carrier wave similar results are obtained at 35 feet. These depths represent total aerial submersion of 20 and 25 feet respectively. Incidentally 30 feet is a very useful submarine depth ; here the periscope is just "blind" and this is a most strategic cruising condition.

Conditions generally improve progressively with wavelength, whilst underwater directional accuracy is quite equal to the best surface conditions.

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F. Woods.

OPTICAL EFFICIENCIES AND DETAIL IN TELEVISION SYSTEMS

The first part of this article, published in the last number of THE MARCONI REVIEW, *No. 47, dealt with the optical efficiencies of Television Systems employing direct scanning methods. In what follows, these arguments are extended to the use of indirect scan, and the article concludes with a brief discussion of the effect of aperture distortion on detail, and of the relations existing between detail and frequency band in television systems.*

Relative Efficiencies of Aperture Disc, Lens Disc and Mirror Wheel using Indirect Scanning.

IN the indirect method of scanning, the problem though very similar to that of direct scanning, is not quite the same. Here we will choose a source of light of intensity I which will be the same in all cases and determine the intensity of the scanning spot on the screen.

(1) Aperture Disc.

The aperture disc method for indirect scan, as illustrated in Fig. 6, is seen to be the same as Fig. 3, except that the arc replaces the photo cell.

If C be the diameter of condenser
f' ,, ,, focal length of condenser
s ,, ,, diameter of source
and b ,, ,, ,, of area of light on disc,

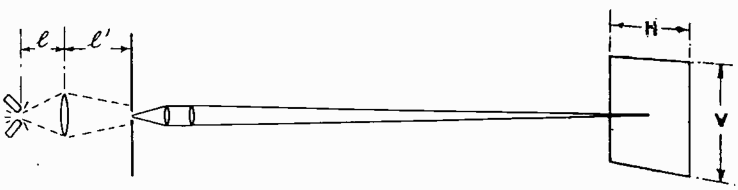

FIG. 6.

then light picked up by condenser in lumens

$$= \frac{4\pi I}{2\pi} \quad \frac{\pi C^2}{4l^2}$$

assuming the light from the source is evenly distributed over a hemisphere.

$\therefore$ Light passing through aperture

$$= L_a = \frac{I\pi C^2}{2l^2} \quad \frac{a^2}{\pi b^2} \; 4 = \frac{2IC^2a^2}{l^2b^2} \text{ lumens}$$

$$\frac{b}{s} = \frac{l'}{l} = \frac{f'_c}{l - f'_c} \quad \therefore \quad \frac{b+s}{b} = \frac{l}{f'_c}$$

$$\therefore \quad lb = f'_c\,(b + s). \qquad \text{Also } a = \frac{D}{rn^2}$$

$$\therefore \quad L_a = \frac{2IC^2\pi^2D^2}{f'^2_c\,(b + s)^2r^2n^4}$$

$$\text{Now } b = \sqrt{h^2 + v^2} = v\,\sqrt{1 + r^2} = na\,\sqrt{1 + r^2}$$

$$= \frac{\pi D}{rn}\,\sqrt{1 + r^2}$$

$$\therefore \quad L_a = \frac{2IC^2\pi^2D^2}{f'^2_c\left(s + \frac{\pi D}{rn}\sqrt{1 + r^2}\right)^2 r^2n^4}.$$

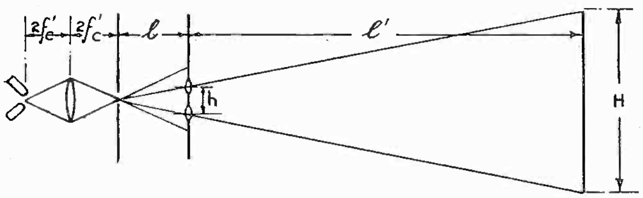

FIG. 7.

(2) Lens Disc.

As before, lumens passing through aperture (v. Fig. 7)

$$= \frac{2IC^2a^2}{f'^2_c\,(b + s)^2}$$

Now b in this case is actually the smallest image of the source obtainable without yielding a cone of light too large to be usefully accommodated on the lens drum. In practice this leads to a value of $b = s$, so that

$$L_a = \frac{IC^2\,a^2}{2f'^2_c\,s^2}$$

Of this, the proportion picked up by one lens on the drum is

$$L_l = \frac{IC^2a^2}{2f'^2_c\,s^2}\;\frac{d^2}{(d + \sqrt{h^2 + v^2})^2}$$

$$\text{Now } \frac{d + \sqrt{h^2 + v^2}}{l} = \frac{C}{2f'_c}$$

$$\therefore \quad L_l = \frac{IC^2a^2d^24f'^2_c}{2f'^2_cs^2l^2C^2}$$

$$= \frac{2\;I\;a^2\;d^2}{s^2\;l^2}$$

$$\text{Now } \quad a = \frac{h}{r\;n} \quad \frac{\pi D}{r\;n^2} \text{ and } l \doteq f'$$

$$\therefore \quad L_l = \frac{2\;I\;\pi^2\;D^2}{s^2\;r^2\;n^4}\;\left(\frac{d}{f'}\right)^2_l$$

(3) Mirror Wheel.

As in the case of the lens drum, the smallest diameter which can in practice be formed on the aperture plate (Fig. 8) is equal to the diameter of the source.

As before

$$L_a = \frac{2\ I\ C^2\ a^2}{f'_c\ (b+s)^2}$$
$$= \frac{I\ \ C^2\ \ a^2}{2\ f'^2_c\ s^2}$$

Light picked up by one mirror

$$= \quad L_m = \frac{I\ C^2\ a^2}{2\, f'^2_c\ s^2} \quad \frac{4\ mk}{\pi\ (m^2 + 4\ k^2)}$$

assuming the beam covers two mirrors.

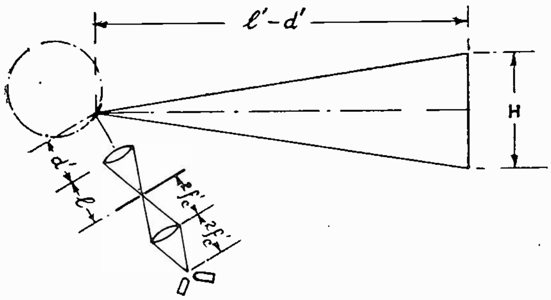

FIG. 8.

But $\dfrac{\sqrt{m^2 + 4\,k^2}}{l} \doteqdot \dfrac{C}{2\ f'_c}$

$$\therefore \quad m^2 + 4\ k^2 = \frac{l^2\ C^2}{4\ f'^2_c}$$

$$\therefore \quad L_m = \frac{I\ C^2\ a^2\ 4\ m\ k\ 4\ f'^2_c}{2\ f'^2_c\ s^2\ \pi\ l^2\ C^2}$$
$$= \frac{8\ I\ a^2\ m\ k}{\pi\ s^2\ l^2}$$

We have $k \doteqdot \dfrac{\pi D}{n}$

Also $\dfrac{H}{2\ (l' - d')} = \tan \dfrac{2\pi}{n} \doteqdot \dfrac{2\pi}{n}$. and d' is negligible in comparison with l'

$$\therefore \quad H = \frac{4\pi}{n}\ l' = Arn$$

$$\therefore \quad A = \frac{4\pi l'}{rn^2} = \frac{l'}{l}\ a$$

$$\therefore \quad a = \frac{4\pi l}{rn^2}$$

$$\therefore \quad L_m = \frac{8\ I\ 16\pi^2 l^2 m\pi D}{\pi s^2 l^2 r^2 n^4 n}$$

$$L_m = \frac{128\ I\pi^2 mD}{s^2 r^2 n^5}$$

Bringing the results together we have that

$$L_a = \frac{2IC^2\pi^2D^2}{f'^2_c \left(s + \dfrac{\pi D}{rn}\ \sqrt{1 + r^2}\right)^2 r^2 n^4}$$

$$L_l = \frac{2I\pi^2D^2}{s^2r^2n^4} \left(\frac{d}{f'}\right)^2_l$$

and $$L_m = \frac{128I\pi^2 mD}{s^2r^2n^5}$$

Before reducing these to a common denominator, we will substitute practical values for some of the constants, and for this purpose we will adopt those values which we have used. It must be remembered that these constants are not the same for each method. For example, a mirror arc could be used for the aperture disc, in which case the ratio $\frac{C}{f'_c}$ is approximately $2\frac{1}{2}$. A mirror arc, however, is unsuitable for either of the other two methods, in which case the corresponding $\left(\frac{C}{f'_c}\right)$ is approximately $1\frac{1}{2}$. Although this does not enter into the formulæ for the flux in the scanning beam, it would be implicit in any comparison of the methods.

We will therefore take an average of $\left(\frac{C}{f'_c}\right) = 2$.

Other values are $s = 1/5$ in., $D = 16$ in., $r = 1$, $m = 3$.

We will assume for the lens drum very good lenses such that $\left(\frac{d}{f'}\right)_1 = 1/3$.

Putting in these figures we have, on reducing the values for the intensity of the scanning spot on the screen to a common denominator,

$$L_a : L_l : L_m :: \frac{1}{\left(1+\frac{356}{n}\right)^2} : \frac{1}{36} : \frac{3}{n}$$

This can be conveniently illustrated by Table I showing the relative efficiencies for varying values of n, the number of lines. Since one is primarily concerned to determine, when designing a television system, which is the most efficient method for a given number of lines, the curves drawn in Fig. 9 indicate the efficiencies for the various systems taking the efficiency for the aperture disc as unity in all cases. From these curves it can be seen that for 85 lines the aperture disc and mirror wheel are practically equal in efficiency. Below this figure, the mirror wheel efficiency increases rapidly, whilst above it decreases rapidly. At about 70 lines the lens drum and the aperture disc methods are equal in efficiency, but above $n = 70$ the aperture disc method is more advantageous. The lens drum and mirror wheel are equal at $n = 110$ approximately. Further it should be noted that the greater the picture ratio, i.e. $\frac{H}{V}$, the greater the relative efficiency of the aperture disc.

Once again at the risk of excessive reiteration it must be emphasised that these figures are approximate and only very general conclusions can be drawn from them. If one were to design the most efficient television system of the three methods herein discussed, the choice would probably be finally decided by external factors such as cost, mechanical advantages or disadvantages, etc., and then each method should be gone through taking the fundamental constants separately for each system.

Distortion in the Television Signal.

As has been mentioned previously, the form of the signal generated by the photocell is independent of the actual method of scanning employed. From the point of view of the receiver, therefore, we have to deal with two types of distortion.

(A) Optical distortion introduced by the finite size of the aperture at the transmitter end.

(B) Electrical distortion occurring in amplification, modulation and transmission.

TABLE I.

Number of lines n	Relative Efficiencies		
	L_a	L_l	L_m
50	1	1·83	3·85
60	1	1·34	2·41
70	1	1·04	1·60
90	1	·68	·82
100	1	·58	·62
120	1	·44	·40
150	1	·32	·23

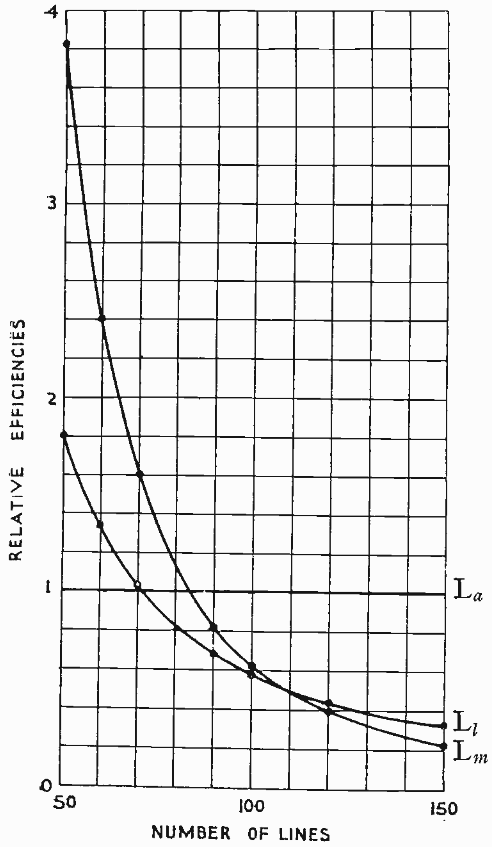

FIG. 9.

At the receiver end the distorted signal from the transmitter will be still more distorted due to the fact that further deformation of signals will occur in the receiver amplifier, and in the light valve, in addition to which the distortion introduced due to aperture effect at the transmitter will be duplicated in the reconstitution of the picture by the receiver aperture, assuming both these apertures to be identical, as is generally the case.

We must therefore confine ourselves to three considerations :—

(A) Distortion occurring due to finite size of aperture in the transmitter and receiver.

(B) Amplitude distortion of the signals which have been already distorted by (A) due to the inability of the electrical circuits to cope with the frequencies involved in the signal.

(C) Phase distortion occurring chiefly at the transmitter, but also, to a smaller extent, in the receiver amplifier.

Aperture Distortion.

Consider, in the case of direct scanning, a line of the image of the subject being scanned at breadth B, one part of which is of low light intensity, and the other of high intensity, the value of light intensity plotted against distance along the line being as shown in Fig. 10 (a).

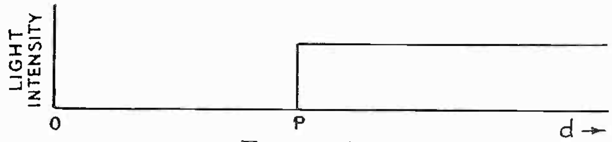

FIG. 10 (a).

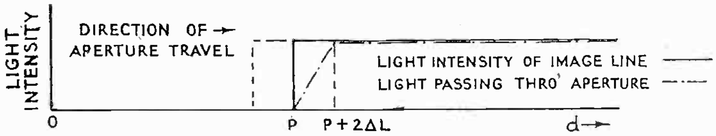

FIG. 10 (b).

If an infinitely narrow aperture traverses this line the light passing through the aperture will rise abruptly at the point P. If the aperture is of finite width, say $2\Delta L$, the rise in light will no longer be abrupt but will rise slowly from a zero as the leading edge of the aperture touches P, and will not attain the final value until the leading edge of the aperture is at a point $P + 2\Delta L$ as shown in Fig. 10 (b).

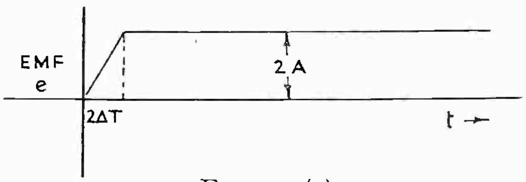

FIG. 10 (c).

The current generated by the photo cell due to the light change shown by the chain line will give rise to an E.M.F., varying with time as shown in Fig. 10 (c), where, for the sake of simplicity, the leading edge of the aperture is supposed to reach P at time $t = 0$, and $2\Delta T$ is the time taken by the aperture to traverse a distance $2\Delta L$.

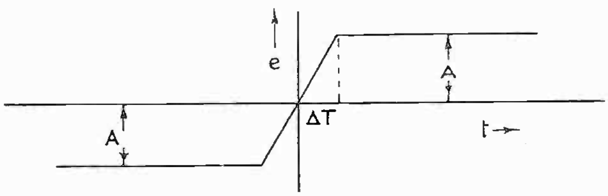

FIG. 10 (d).

Subtracting the D.C. component of value A from this curve and displacing it by amount ΔT to the left, we have an E.M.F. surge as shown in Fig. 10 (d).

The analysis of the type of transient represented in the figure is discussed in "Transmission Networks and Wave Filters" (Shea, pp. 427-432). It is shown there that the transient can be represented by

$$e = \frac{2A}{\pi}\int_0^\infty \frac{1}{\omega}\left[\frac{\sin \omega \Delta T}{\omega \Delta T}\right] \sin \omega t \, dw$$

in place of the corresponding

$$e = \frac{2A}{\pi}\int_0^\infty \frac{1}{\omega} \sin \omega t \, dw$$

for the square fronted wave which would be produced by an infinitely narrow aperture. The distortion produced by the aperture of width $2\Delta T$ is therefore one of amplitude only and can be corrected by a suitable equalising network, providing ΔT is known. It would therefore be theoretically possible to reproduce one change of light intensity to any desired accuracy by means of electrical networks.

It is necessary, however, to fix upon a definite value of ΔT for design purposes, and we must choose this value from other considerations, as equalising methods can clearly be applied afterwards to whatever value of ΔT is obtained.

The best method of approach will be to examine the nature of the light variations with which we have to deal, and the frequencies contained in the E.M.F. waves produced thereby, taking into consideration aperture distortion.

This examination involves the analysis of some form of light variation curve. This curve will, in the general case, be of a transitory nature, and therefore it is incorrect, on the one hand, to postulate steady state conditions for the light variations in an image which is not stationary, and on the other, it is clearly impossible to discuss the matter from a transient point of view. In the first case we shall be assuming a state of affairs which cannot possibly obtain for more than a very short time interval, and in the second we shall not be able to handle the results quantitatively, involving, as they do, Fourier Integral Methods.

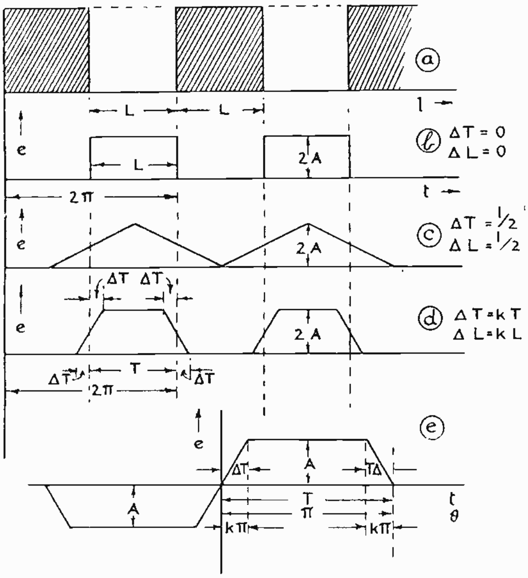

FIG. 11.

Remembering, however, that we wish to determine ΔT, we shall adopt the former method, as being the lesser of two evils, and so we shall assume as a start a definite type of periodic light variation over a picture line, determine how this is distorted and what the frequency distribution of the distorted wave is when scanned by a definite shaped aperture, and finally, use the results obtained to determine the optimum shape of aperture.

Assume a distribution of light and shade over one picture line as at (a) Fig. 11.

Let L = Width of black or white element.

T = Time in which Aperture traverses L.

$2\Delta L$ = Width of Aperture.

$2\Delta T$ = Time in which Aperture traverses its own width.

$$k = \frac{\Delta T}{T} = \frac{\Delta L}{L}$$

In (b) is shown a square wave formation which will be of period 2π corresponding to one complete passage of the aperture over a black and white picture element, when $\Delta L = \Delta T$ is infinitely small. When $\Delta L = L/2$ or $\Delta T = T/2$ the wave will be as in (c) Fig. 12, and in the general case when $\Delta T = kT$ or $\Delta L = kL$ we shall obtain a distorted wave of shape (d) Fig. 12. Choosing our origin and allowing for a constant term of amplitude A we have, if $f(\omega t)$ represents the wave

$$f(\omega t) = A + \sum_{n=1}^{n=\infty} a_n \sin n\omega t$$

and it remains to determine the form of the sine series.

It is shown in the appendix that

$$a_n = \frac{2A}{n^2\pi^2 k} \sin n\pi K \left\{1-(-1)^n\right\}$$

so that

$$f(\omega t) = A + \sum_{n=1}^{n=\infty} \frac{2A}{n^2\pi^2 k} \sin n\pi k \left\{1-(-1)^n\right\} \sin \omega t$$

In other words, the complete signal can be represented by a sine series, the amplitude of the fundamental wave of period 2T being

$$a_l = \frac{4A}{\pi^2 k} \mathit{sin}\ \pi k$$

the amplitude of the first harmonic zero, that of the second $\left(\text{of period } \frac{2T}{3}\right)$

$$a_3 = \frac{4A}{9\pi 2k} \sin 3\pi k$$

and so on.

Plotting a_1, a_3 a_5 .... against $k = \frac{\Delta T}{T} = \frac{\Delta L}{L}$ we have a series of curves as shown in Fig. 12.

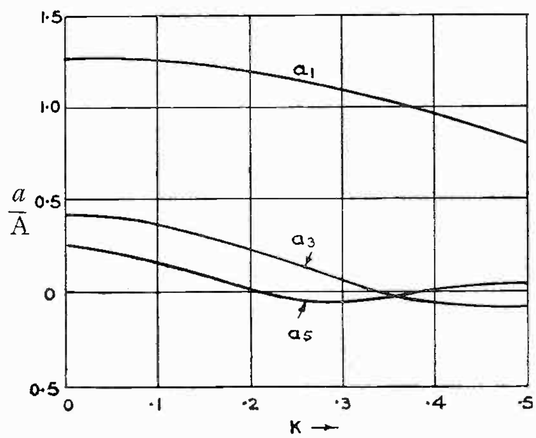

FIG. 12.

This shows that at a point when $k = .33$ or where $\Delta L = 1/3$ L, the amplitudes of the harmonics become negligible. This means that when the exploring aperture has a width equal to 2/3 the width of the picture element, i.e. 2/3 L, assuming the highest frequency we can transmit to be in the neighbourhood of $\frac{1}{2\pi}$, the square wave can be represented with minimum distortion by a pure sine wave of period 2T, and of amplitude approximately equal to A.

Now the frequency $\frac{1}{2T}$ corresponds to the well-known figure of $\frac{pn}{2} r$ where

p = number of pictures transmitted per second.

n = number of scan lines.

r = picture ratio.

The next frequency which contributes to the square wave form is $\frac{3}{2\mathrm{L}}$ which represents a 200 per cent. increase in the frequency band, which is, in practical systems, so serious an increase as to be immediately ruled out Hence we can fix the optimum aperture width definitely as 2/3 L for design purposes.

The next question is as to the choice of the length of the aperture perpendicular to the direction of scanning. Unfortunately, this cannot be determined quantitatively as the methods of resolution in the two directions are inherently different. In both directions, it is true, the resolution is intimately bound up with the dimensions of the aperture, inasmuch as we can say broadly that the smaller the aperture the greater the amount of detail that will be seen. There is this great difference, however, between the two directions. In the direction parallel to the direction of scanning the light variations are continuous, but in the direction perpendicular to the direction of scanning the light variations are discontinuous. Hence we have to determine what form or type of correlation, if any, exists between the two directions. Now we can take as a basis of calculation the *resolution* of the picture in the two directions. That is to say, given two black bars in the picture, say perpendicular to the direction of scanning, we can determine how close together they can approach and still be resolvable. The minimum distance between the two bars for bare resolution will be a function of the dimension of the scanning spot in the direction parallel to the direction of scanning. We can by similar treatment for the bars placed parallel to the direction of scanning again obtain this minimum distance which in this case will be another function of that dimension of the scanning spot in a direction at right angles to the direction of scanning. By equating these two minimum distances, a relation is obtained between the two dimensions of the scanning aperture, assuming of course a rectangular aperture.

Unfortunately, although these two bars will be equally resolved in both directions by such an aperture, it does not follow that they will be equally sharp or equally defined, In actual fact this will not be the case. If therefore we wish to confine our attention to definition and not resolution, we must use another criterion. This is immediately provided by commercial photography, where what primarily decides the quality of a lens system is the diffusion of the image when the object is an infinitely small spot. The corresponding criterion in the case of a received television picture is the diffusion of an edge or boundary between two degrees of intensity, e.g., black and white. Once again a definite relation between the length and breadth of the aperture can be very simply obtained, but the result is unsatisfactory owing, as previously mentioned, to the fact that the light variations are continuous in one direction and discontinuous in the other. Inevitably, there is a physiological difference as far as the eye is concerned, particularly as in general the boundary appears perfectly defined but merely displaced from its true position.

These are the actual facts, which it will be seen admit of no rigorous quantitative results being obtained. One method of obtaining definite aperture dimensions is to determine what are the rectangular dimensions of the smallest necessary element in the picture we wish to transmit, to fix the aperture breadth (we shall assume horizontal scanning in what follows, though the results will apply equally well to vertical scanning if the dimensions of the aperture are reversed) as 2/3 the breadth of this element, and the aperture length as equal to the length of the element.

Now this element can conveniently be taken as the iris of the eye in the case of a picture of a head. The length of the iris of the eye bears an approximately constant relation to the length of the face. The iris has actually very nearly the same breadth as length (regarded from a television point of view) and the ratio of lengths is $\frac{1}{25}$

This leads us to the conclusion that the aperture (or its image) should be $\frac{2}{3}L \times L$ where L is $\frac{1}{25}$ H, H being the height of the image. In other words, to obtain satisfactory definition on a head, we need 25 lines as minimum. For a head and shoulders this figure should be increased to 30 lines approximately. For three-quarter length scan, where facial detail is not so necessary, the length of the smallest element we need to consider may be taken as $\frac{3}{4}$ in. and the total length of scan as 50 in., i.e., the number of scan lines should be 70, and for full-length scan, approximately of length 75 in., 100 lines should be used.

These figures, it is admitted, are, at best, empirical, but they represent better guides for design purposes than do most of the highly theoretical figures which have been given from time to time and which have, after all, only very doubtful justification.

Once the number of scan lines and the aperture shape has been fixed, it merely remains to determine the ratio of length to breadth of the complete image. This may be fixed from æsthetic considerations, in which case a ratio of 3 to 4 is very nearly ideal, or from necessity to embrace a given type of subject.

Appendix.

Derivation of relation used on page 16.
Referring to Fig. 11 (e) :—

From $t = 0$ to $t = K\pi$ $\qquad f(x) = \frac{A\,x}{K\pi}$

$$a'_m = \frac{2}{\pi}\int_0^{k\pi} \frac{A}{k\pi}\,x \sin mx\,dx$$

from $t = K\pi$ to $t = \pi - K\pi$ $\qquad f(x) = A$

$$a''_m = \frac{2}{\pi}\int_{k\pi}^{\pi - k\pi} A \sin mx\,dx$$

from $t = \pi - K\pi$ to $t = \pi$ $\qquad f(x) = \frac{A}{K} - \frac{A}{K\pi}x$

$$a'''_m = \frac{2}{\pi}\int_{\pi - K\pi}^{\pi}\left(\frac{A}{K} - \frac{A\,x}{K\pi}\right)\sin mx\,dx$$

$$a'_m = \frac{2A}{\pi^2 K}\left[\frac{\sin mx}{m^2} - \frac{x \cos mx}{m}\right]_0^{K\pi}$$

$$= \frac{2A}{m\pi^2 K}\left[\frac{\sin mK\pi}{m} - K\pi \cos m K\pi\right]$$

$$a''_m = \frac{-2A}{m\pi}\left[\cos mx\right]_{K\pi}^{\pi - K\pi}$$

$$= \frac{2A}{m\pi}\left[\cos mK\pi - \cos m\pi (I-K)\right]$$

$$a'''_m = \frac{2A}{mK\pi}\left[-\cos mx\right]_{\pi(1-k)}^{\pi} - \frac{2A}{K\pi^2}\left[\frac{\sin mx}{m^2} - \frac{x \cos mx}{m}\right]_{\pi(1-k)}^{\pi}$$

$$= \frac{2A}{mK\pi}\left[\cos m\pi (I-K) - \cos m\pi\right] - \frac{2A}{mK\pi^2}\left[-\frac{\sin m\pi (I-K)}{m}\right.$$

$$\left. - \pi \cos m\pi + \pi(I-K) \cos m\pi (I-K)\right]$$

$$\therefore \quad a_m = \frac{2A}{m^2\pi^2 K} \sin m\pi K + \frac{2A}{m^2 K\pi^2} \sin m\pi (I-K)$$

$$= \frac{2A}{m^2\pi^2 K}\left[\sin m\pi K + \sin m\pi (I-K)\right]$$

$$= \frac{2A}{m^2\pi^2 K} \sin m\pi K \left\{1-(-1)^m\right\}$$

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from $t = \pi - K\pi$ to $t = \pi$ $\qquad f(x) = \frac{A}{K} - \frac{A}{K\pi} x$

$$a'''_m = \frac{2}{\pi}\int_{\pi - K\pi}^{\pi} \left(\frac{A}{K} - \frac{A\,x}{K\pi}\right) \sin mx \, dx$$

$$a'_m = \frac{2A}{\pi^2 K}\left[\frac{\sin mx}{m^2} - \frac{x \cos mx}{m}\right]_0^{K\pi}$$

$$= \frac{2A}{m\pi^2 K}\left[\frac{\sin mK\pi}{m} - K\pi \cos m K\pi\right]$$

$$a''_m = \frac{-2A}{m\pi}\Big[\cos mx\Big]_{K\pi}^{\pi-K\pi}$$

$$= \frac{2A}{m\pi}\Big[\cos mK\pi - \cos m\pi (1-K)\Big]$$

$$a'''_m = \frac{2A}{mK\pi}\Big[-\cos mx\Big]_{\pi(1-k)}^{\pi} - \frac{2A}{K\pi^2}\left[\frac{\sin mx}{m^2} - \frac{x \cos mx}{m}\right]_{\pi(1-k)}^{\pi}$$

$$= \frac{2A}{mK\pi}\Big[\cos m\pi (1-K) - \cos m\pi\Big] - \frac{2A}{mK\pi^2}\Big[-\frac{\sin m\pi (1-K)}{m}$$

$$-\pi \cos m\pi + \pi(1-K) \cos m\pi (1-K)\Big]$$

$$\therefore \quad a_m = \frac{2A}{m^2\pi^2 K} \sin m\pi K + \frac{2A}{m^2 K\pi^2} \sin m\pi (1-K)$$

$$= \frac{2A}{m^2\pi^2 K}\Big[\sin m\pi K + \sin m\pi (1-K)\Big]$$

$$= \frac{2A}{m^2\pi^2 K} \sin m\pi K \left\{1-(-1)^m\right\}$$

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TERMINAL EQUIPMENTS

In the following article a short introduction deals with the need of special precautions on radio-telephone circuits, and is followed by a brief description of hybrid coil properties, showing their inability to meet all the requirements of these circuits. A general description of conditions at a radio-telephone terminal is then used to develop a basis for an anti-singing device of general type. The apparatus used in such a device is next briefly described so that the mechanism of its operation may be explained in greater detail. Finally, the handling of this equipment, and the practical form it takes in the Marconi R.C.49 terminal equipments is discussed.

Introduction.

THAT radio-telephone circuits require some mechanism for switching between the transmitter, the trunk line, and the receiver, can be seen to follow from quite simple facts. At the junction point of the trunk, the transmitter and the receiver lines, a brief survey will show that these lines do not operate under the same conditions. The trunk line must carry speech in either direction along it. The remaining two lines are only required to carry speech in one direction, and in fact include valve circuits that ensure this.

Carrying the survey a step further, it is seen that the paths speech currents can travel effectively are from the trunk to the transmitter line in one direction, and in the reverse, from the receiver line to both the trunk and transmitter lines. This last possibility is undesirable for a number of reasons, of which only the more important need be mentioned here. If received signals can reach the transmitter at any time and the receiving conditions do not provide a high discrimination against the local transmissions, oscillations can occur around the trunks, transmitter and receiver. The possibility also has an effect on the apparatus at the far end of the radio-circuit. For noise from the local receiver will modulate the local transmitter, and, at the far end of the radio-circuit, will have the effect of degrading the signal-to-noise ratio. The most serious effect, however, is that if the level of speech sent to the trunk from the receiver equals that supplied by the trunk for transmission, then the transmitter would be fully modulated by locally received speech. It is therefore necessary to provide directional discrimination at the junction point between these speech paths so that speech can pass from and to the trunk, but cannot pass from the receiving circuits outwards along the transmitting path. This discrimination is provided usually by two distinct sets of apparatus, known respectively as the hybrid coils and the anti-singing apparatus.

Hybrid Coils.

Hybrid coils are well known in telephony and may be regarded as in principle a bridge circuit of the mutual inductance type. The transmitting trunk, Fig. 1, is connected to two windings in series aiding on one core, and the receiving trunk is similarly connected to two windings on a second core. Each of these cores carries two further windings and the exchange trunk is connected to one winding on each core in series. The remaining windings are connected in series to an external network, the connection between these windings being in opposite sense to those connected to the exchange trunk. With such an arrangement, speech currents arriving on the exchange trunk will cause E.M.F.'s in the transmitting and receiving paths, and these in turn will cause opposing E.M.F.'s across the network. That is, if all the circuit components are balanced, speech currents arriving on the exchange trunk will cause no current in the network but equal E.M.F.'s in the transmitting and receiving circuits. On the other hand, under these ideal conditions, speech currents from the receiving trunk circuit will cause E.M.F.'s to arise in the exchange trunk and in the network. The currents in these two latter circuits will pass in opposition through the windings coupled to the transmitting trunk. If then the E.M.F.'s in the exchange trunk and network circuits are equal, the coils balanced and the exchange trunk and network of the same impedance, no E.M.F. will arise in the transmitting circuits.

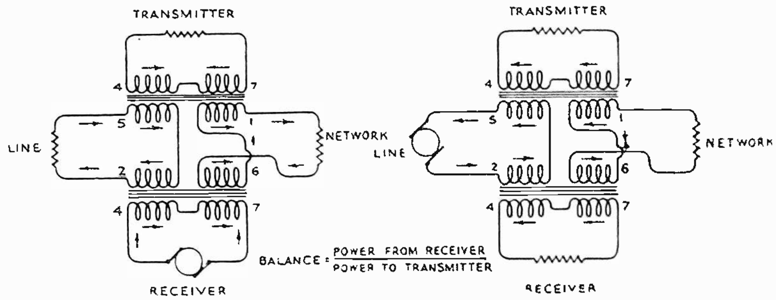

FIG. 1.

Practical considerations have a major bearing on the possibility of such a perfect balance. The commercial limits to which coils, etc., can be made set a limit to the degree of balance : but a much more serious cause of error lies in the variation of impedance of the exchange trunk as different subscribers use the circuit, each such connection offering a different impedance-frequency characteristic to be simulated by a network. The practice adopted is to provide a small number of networks, chosen to simulate the mean impedance of groups of such connections, e.g., the technical operator, local subscribers, long distance connections, etc.

The hybrid coils thus provide partial, but insufficient discrimination. Moreover, if any part of received speech power sent down the exchange trunk is reflected back as an echo, the hybrid coils will be unable to distinguish between such an echo and speech from the exchange trunk. Such an echo would therefore be transmitted, and would give rise to the same difficulties as the re-transmission of received energy. For these reasons anti-singing devices are used in addition to hybrid coils.

Development of Anti-Singing Device.

Anti-singing devices are used in several forms, the form most widely adopted being that in which, during the absence of speech, the receiver is connected to, but the transmitter disconnected from the hybrid and trunk. On the occurrence of speech for transmission, the reverse connection is made, the transmitter being connected to and the receiver disconnected from the hybrid and trunk. Thus the trunk is connected to either the transmitter or the receiver but never to both at the same time, and possible paths around which echo or oscillation can occur are avoided.

Such a device will have some form of switch in the main transmitting and receiving paths, apparatus for controlling these switches and apparatus connecting the controlling circuits to the sources of operating energy. These groups are referred to as the transmission, control, and input apparatus.

Initially, consider a simple form, Fig. 2 (a), in which a switch is placed in the transmitting path and a second in the receiving path. Suppose that these switches are interlocked so that only one is made at any instant, and suppose the change-over action to be controlled by the energy in the connection between the transmitting switch and the hybrid.

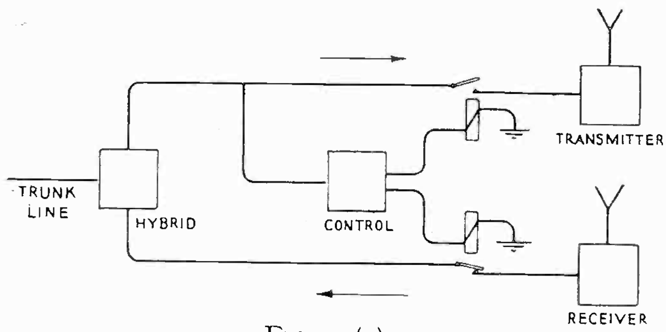

FIG. 2 (a).

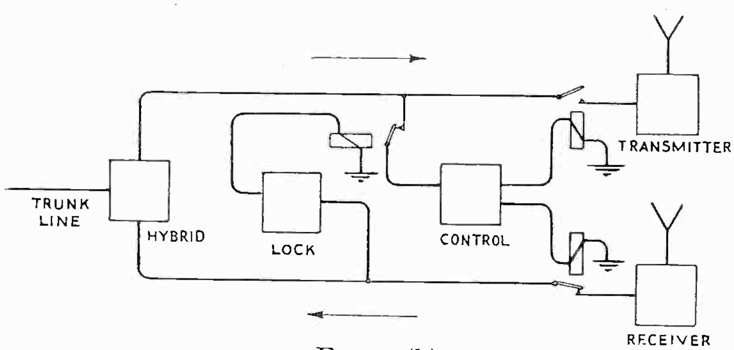

FIG. 2 (b).

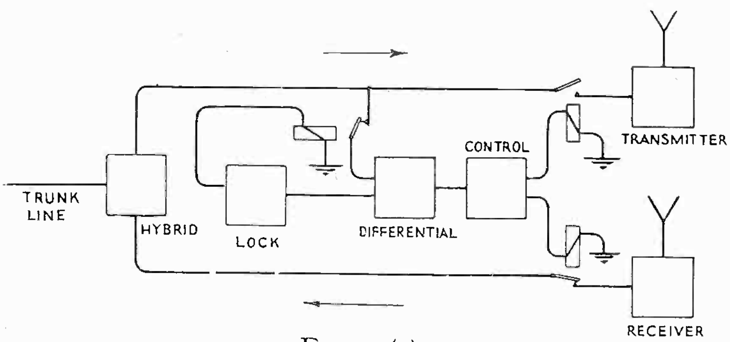

FIG. 2 (c).

Now when no speech is passing, received noise will be passing from the receiver. This received noise will follow the path of received speech to the trunk through the hybrid, and since the hybrid will not be perfectly balanced, the received noise will in part travel along the transmitting path from the hybrid. Similarly, trunk noise will follow the transmitting speech path through the hybrid. With no speech passing, then, there is received noise on the main receiving path, and on the transmitting path received noise and trunk noise.

When received speech occurs, similar conditions will obtain, the received speech adding to the received noise at all points. That is, the main receiving path carries received speech and received noise, while the transmitting path carries received speech, received noise and trunk noise.

When transmitted speech occurs, the conditions before the switches operate will be—on the main receiving path, received noise ; on the main transmitting path, received noise, trunk noise and speech for transmission. Once the switches have operated, there will be no energy on the main receiving path, and on the transmitting path there will be only trunk noise and speech for transmission.

The conditions which the control apparatus must fulfil can now be specified. This apparatus must not operate when no speech is passing, i.e., when the input to it is that due to trunk noise and the received noise reaching the main transmitting path. Neither must it operate when received speech is passing, i.e., when its input is increased by the received speech reaching the main transmitting path. The apparatus must operate when its input comprises received noise, trunk noise and speech for transmission. The margin for operation will then be that between the levels of received speech and speech for transmission as they occur in the main transmitting path. Such a simple device could not then send a greater level of received speech to the trunk than the level on the main transmitting path of speech for transmission plus the hybrid balance less the margin necessary between non-operation and operation of the control apparatus. A distant subscriber, however, will provide a low level of speech for transmission and possibly a poor hybrid balance, while requiring a high level of received speech to be sent to him from the terminal.

If a third switch be introduced between the input to the control apparatus and the main transmitting path, Fig. 2 (b), and if this third switch or "lock" be controlled by the energy in the main receiving path, an improvement is possible. For suppose this lock to be a normally closed switch, opened only when the energy in the receiving path is that of both received speech and noise, then in the absence of any speech, the original conditions are unchanged, but during received speech the control apparatus receives no input as the lock is operated. At the time speech for transmission reaches the control apparatus, the original conditions still hold. Further, if the input controlling the lock is from between the switch in the main receiving path and the hybrid, once the control apparatus has operated, the lock cannot be operated and so cannot cause interruptions in the transmission. Since speech for transmission from the trunk causes signals on both the transmitting and receiving side of the hybrid, a repeater or other one-way device must be inserted in the main receiving path between the hybrid and point from which the lock is controlled.

The conditions for the control apparatus now are that it must not be operated by the trunk noise and the received noise reaching the main transmitting path, but must be operated when this energy is increased by the presence of speech for transmission. The conditions for the lock are, of course, that it must not be operated by the received noise in the main receiving path, but must be operated when this energy is increased by the occurrence of received speech.

A further improvement will be made if the effect of received noise on the control apparatus can be overcome—an effect which now occurs only in the absence of speech and at the instant when speech for transmission reaches the apparatus. Under the latter condition, the main transmitting path is carrying speech for transmission, trunk noise and received noise, while the main receiving path is carrying only received noise. If, then, part of the energy in the main receiving path can be diverted and made to oppose that reaching she control apparatus from she main transmitting path, Fig. 2 (c), it will be a matter of gain control to obviate the effect of received noise on the control apparatus. The margin for the control apparatus will then be non-operation on trunk noise and operation on trunk noise with speech for transmission. Further, ideally, the maximum level of received speech sent to the trunk from the terminal would be independent of the level at the terminal of speech for transmission. Even an approach to such an arrangement will be a considerable improvement.

Apparatus.

The preceding section has shown the desirability of a type of anti-singing device in which the main transmitting and receiving paths include switches jointly operated by control apparatus so that only one path is available at any instant. This control apparatus is required to operate on the difference between the outputs of two sets of apparatus, respectively deriving their energy from the transmitting and receiving paths to the hybrid and designated as " input apparatus." In addition, a " lock " has been mentioned to be operated by speech in the main receiving path in order to paralyse the transmitting input apparatus.

Further study of such a system will be rendered easier by the description of an actual system built around these principles. A brief description is therefore inserted here of the circuits used in Marconi " International " grade terminal equipments.

The general schematic of the system is shown in Fig. 3. It will be seen that the transmission apparatus in the main transmitting and receiving paths is identical, consisting in each case of a line filter preceding a switch. The type of switch used takes the form of an amplifier, rendered operative or inoperative according to the grid bias applied to a balanced stage. These switches are referred to as " suppressor repeaters."

The input apparatus consists of two parts—the transmitting and receiving input apparatus. In each case the apparatus is connected to its respective main speech path through a monitoring coil bridging that path on the hybrid side of the suppressor repeater, and succeeded by a band-pass filter. These monitoring coils and filters are designated as the transmitting and receiving monitoring coils and A.S.D. filters respectively. The output from the filters passes to gain controls and amplifiers, referred to as the transmitting and receiving differential gain controls and differential transmitting and differential receiving amplifiers respectively.

The control apparatus includes two parts—the " lock " and the apparatus for combining the two outputs from the " input " apparatus in opposition so as to change the grid bias of the suppressor repeaters as required. The " lock " derives its input from across that to the differential receiving gain control, and when operated paralyses a stage in the differential transmitting amplifier. The remainder of the control apparatus consists of two balanced detectors, connected one to each output of the " input apparatus," and arranged so that the D.C. outputs of these detectors oppose. These two detectors together form the " differential," and the difference of their D.C. outputs is used to operate a D.C. amplifier—the " bias control." The bias control provides the necessary linkage between the suppressor repeater grid voltages to prevent both the main speech paths being available at any instant, and also changes these voltages on receiving the necessary D.C. input. For convenience, the bias control and lock are mounted on the one panel. Indication of the behaviour of the differential output is made available by a meter mounted on the gain control panel.

Some of the above groups of apparatus require special supplies. These supplies are provided by the " A.S.D. supply potentiometer " from the normal 24 and 130 volt batteries, and may be adjusted in some cases. The panel carrying this potentiometer also carries means of measuring the currents from these special supplies. This last group is referred to as the " auxiliary " apparatus.

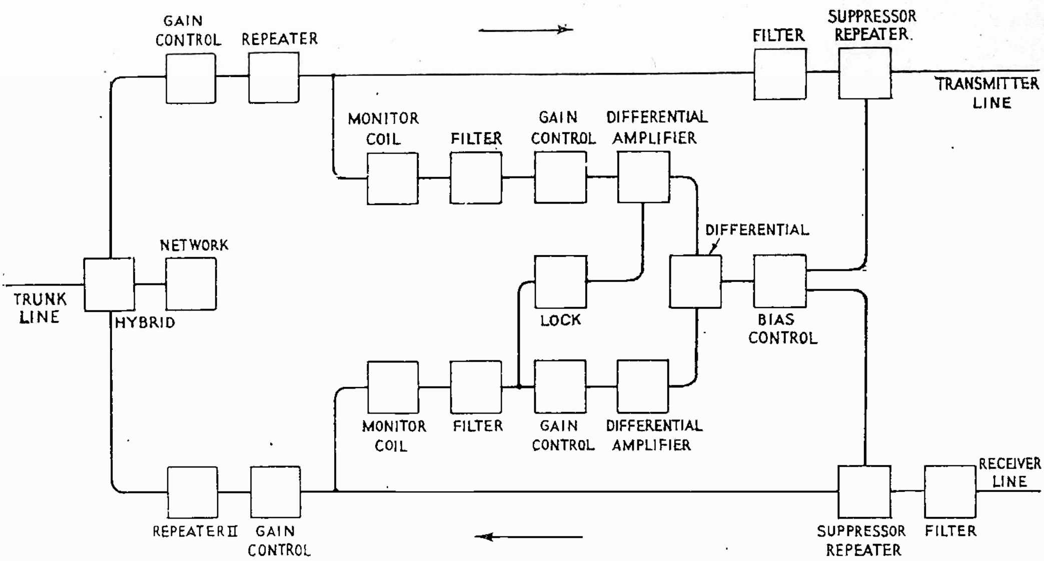

FIG. 3.

For the present purpose, detailed descriptions of the apparatus are not necessary except in the case of the " differential," " bias control " and " lock." Of these the " differential," Fig. 4, consists of two pairs of push-pull diode detectors, having all their cathodes commoned and the centre point of the input transformer for each pair connected by a resistance and shunt condenser to these cathodes. The direct current output is taken from similar points in each of these loads and is therefore proportional to the difference between the input voltages. An indicating meter is symmetrically tapped across part of this total output load, of which latter one terminal is taken to a supply voltage, the other furnishing the input to the bias control through a resistance and small shunt condenser. This last circuit has a negligible time-constant.

The " bias control," Fig. 5, is a simple direct-current amplifier, having the anode resistance of the first valve shunted by a manually controlled condenser. The potential of this first valve anode controls the grid bias of the balanced stage in the receiving suppressor repeater, and that of the second valve, the bias of the similar stage in the transmitting suppressor repeater. All supplies for this bias control are derived from the main batteries through the auxiliary apparatus. The connections are such that the first bias control valve is normally past cut-off in the absence of any output from the differential.

The lock circuits, Fig. 6, are formed by a normal amplifying stage of controlled gain and high impedance input, transformer-coupled to the grid of a second valve.

The anode circuit of this second valve passes through one widening of a three-three-winding transformer. Of the remaining windings, one is connected to a metal rectifier, the other to a diode detector. The output load of the metal rectifier is formed by a series of resistances shunted by a condenser, and to a point in this resistance load is connected one secondary terminal of the intervalve transformer. One end of the rectifier load and the second valve cathode are connected to points on the A.S.D. supply potentiometer, in such a manner that the D.C. output from the rectifier drives the second valve up from the cut-off point. The design is such that with increasing input, the alternating current in the three-winding transformer increases gradually at first and then very rapidly. Beyond this point the increase is again gradual. The voltage across the diode detector behaves in a corresponding way, and, since the diode has a negative bias, the diode direct current output shows only a sudden increase at a particular input level. This diode direct current output establishes a large negative voltage across the diode condenser-resistance load. Since this load is connected between the bias point and grid of the first valve in the differential transmitting amplifier, operation of the lock effectively paralyses this amplifier and prevents activation of the transmitting suppressor repeater.

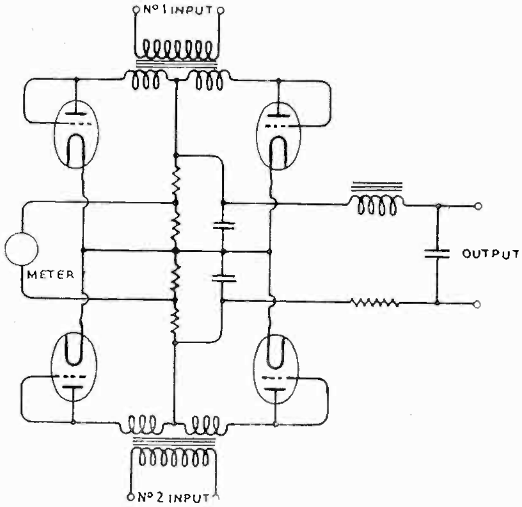

FIG. 4.

Mechanism of Operation.

The general operating conditions led to a choice of system, and such a system has been broadly outlined. The purpose of the following section is to describe how far the means adopted meet conditions. The mechanism whereby speech for transmission activates that path and paralyses that for received speech is first described, then the effects of received noise, those of received speech, and finally those of echoes.

Activation for Transmission.

Speech currents for transmission will pass through the preliminary gain control and repeater and will then pass in part through the line filter to the transmitting suppressor repeater and in part through the A.S.D. transmitting filter and gain control to the transmitting differential amplifier. The currents reaching the suppressor repeater will be limited to frequencies from 250 to 2,750 p.p.s., while those reaching the differential amplifier will lie within the band 500 to 2,500 p.p.s. The differential amplifier will therefore receive a certain amount of protection against low frequency disturbances and will receive the frequency band in which lies the maximum response of a subscriber's microphone.

The differential amplifier has a frequency characteristic which furthers this frequency discrimination against noise, before the amplifier output reaches the differential. The result of an output to the differential from the transmitting side is to cause a direct current voltage to arise across the differential output in such a sense as to make the grid of the first bias control valve more positive.

As this positive sweep of the bias control valve increases, the valve becomes increasingly conductive. Correspondingly the valve anode becomes increasingly negative with respect to its supply point. Since this anode is connected to the grids of the receiving suppressor repeater and to the second bias control valve grid, the repeater becomes paralysed and the second bias control valve ceases to conduct. As this second bias control valve becomes non-conducting, the potential of its anode will become less negative and will finally be that of its anode supply voltage. The transmitting suppressor grids are connected to this second valve anode, so that when the valve is non-conducting, the repeater will be activated.

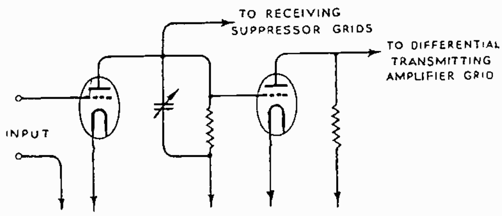

FIG. 5.

It will be seen that during this activation process, the condenser shunting the first bias control anode resistance will become charged through the comparatively low resistance of the first valve anode-cathode path. When restoration takes place on speech for transmission ceasing, however, this path is no longer of low resistance since the differential output has disappeared and the valve is once more beyond cut-off. The condenser discharge is therefore through the anode resistance and is correspondingly slow. Since the potential of the first bias control anode controls the whole mechanism, it follows that the whole restoration is slow—that is the paralysis of the transmitting and activation of the receiving suppressor repeaters. It should be noted that the voltage arising across this anode condenser-resistance circuit on activation is limited to that of the anode-cathode supply voltage to the first valve, so that the restoration time becomes independent of the input voltage to the bias control after this has reached a certain value. Further, since the valve grids associated with this circuit all become more negative on activation, the anode resistance is in shunt only with grid-cathode insulation conductances during the first part of restoration. In the final stages of restoration this resistance may be effectively diminished by grid current due to the positive contact potentials in the valves.

It is necessary that the receiving suppressor repeater should cause a high attenuation in the path through it before the transmitting suppressor repeater ceases so to do in the transmitting path. This is arranged by the choice made of the voltages of the various supplies. The suppressor repeaters are designed to offer an attenuation of more than 60 dB. when their grids are more than 2 volts negative to their cathodes. The second valve of the bias control is arranged so that when this voltage exists between its grid and cathode, the valve plate-cathode resistance is sufficiently low for the grids of the transmitting suppressor repeater to be only just approaching the activated condition. By this means the sum of the two suppressor repeater equivalents is prevented from falling below at least 60 dB. loss.

Received Noise.

It has been mentioned in the general theory, that, with no speech passing, received noise is liable to pass through the receiving chain, reach the hybrid coils and appear in the transmitting chain at levels comparable with the level of speech for transmission. While the mechanism just described for the activation of the transmitting path affords some frequency discrimination between speech and noise, further steps are necessary to prevent this received noise causing false operation. The principle whereby part of the energy in the receiving chain is used to annul the effect of received noise in the transmitting chain has already been described.

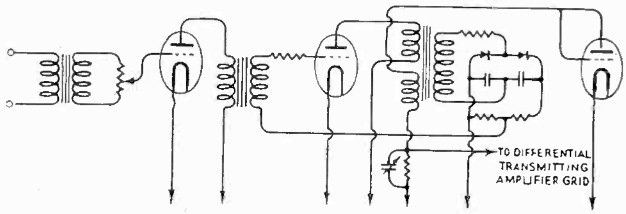

FIG. 6.

Immediately after the receiving suppressor repeater output, the receiving chain is bridged by a monitoring coil, whose output passes through the receiving A.S.D. filter, gain control and differential amplifier. The output of this amplifier is taken to the differential, on the output voltage of which it has the opposite effect to that connected to the transmitting side. That is, the receiving side of the A.S.D. tends to drive the first valve of the bias control further past cut-off, the transmitting side to drive it up from cut-off. The D.C. bias control input is thus the difference of these two outputs. Since the output from the receiving side is due to received noise and so is that on the transmitting side, it follows that, by use of gain controls, the two outputs can be balanced, in the absence of speech, so that the mean D.C. input to the bias control is zero. In seeking this balance, there are two circuits involved. On the transmitting side—receiving gain control repeater II., hybrid coils, transmitting gain controls, transmitting repeater I., A.S.D. monitoring coil, filter, gain control and differential amplifier. On the receiving side—A.S.D. monitoring coil, filter, gain controls and differential amplifier.

The gain of these two circuits has to be made equal for balance, so that the effective gain of the receiving A.S.D. gain control and differential amplifier, must exceed that of the transmitting A.S.D. gain control and differential amplifier by the effective total gain of the main receiving gain control, repeater II., hybrid coils, transmitting gain control and repeater I. This last gain will be altered in practice in several ways. The main receiving gain control will be used to control the received speech level to the trunk, and will not therefore be frequently changed. The loss in passing from one four-wire side of the hybrid to the other will depend on the network and two-wire termination and will in each such case have a different frequency characteristic. This loss will therefore be subject to random changes. The gain of the main transmitting gain control and repeater will depend on the strength of the speech for transmission reaching the terminal. To maintain a balance under these conditions, then, the receiving A.S.D. gain control would have to be adjusted for each alteration in received speech level to line, trunk connected and level of speech for transmission at the terminal.

It is pertinent then to consider the results of an inaccurate balance. Suppose the gain of the transmitting side of the anti-singing device to be adjusted so that satisfactory transmission is affected. The D.C. input to the bias control on such transmitted speech is then the "operating input." If now received noise occurs, the D.C. voltages will arise on either side of the differential, but since the differential is of the linear type, the difference of these two voltages with a perfect balance will be zero and independent of their actual value. That is, with a perfect balance, received noise will not affect the minimum level for successful transmitted speech. Suppose now that the balance is not perfect and that in the absence of speech the receiving side of the differential has a higher output than the transmitting side. The first valve of the bias control will therefore receive an additional negative bias; and a correspondingly higher level of speech for transmission will be necessary to operate it. Conversely, if the output of the transmitting side exceeds that of the receiving side, the bias control receives less negative bias and a lower level of speech for transmission will operate it. A further unbalance in the same direction will thus cause false operation of the device. Note that in this condition, the false operation will suppress the incoming noise path and that therefore the device will in practice go through cycles of operation and restoration. In summary, then, excessive receiving gain penalises speech for transmission, excessive transmitting gain eventually causes false operation.

It should be noted that the bias control is operated by a definite voltage, and that this voltage will correspond to different degrees of unbalance in decibels according to the levels existing. This will be seen from the fact that 1 dB. unbalance at 100 volts means an unbalance voltage of 12.2, at 10 volts 1.22 and at 1 volt 0.122. Alternatively 1 volt unbalance means 0.1 dB. unbalance at 100 volts, 0.85 dB. at 10 volts, and 6 dB. at 1 volt approximately. Hence, the greater the noise level at the two sides of the differential, the more important is the balance.

Now the gain on the transmitting side of the anti-singing device is set by that necessary for the successful transmission of speech. Hence the level of received noise at the differential will depend on the noise level at the hybrid four-wire output and the gain between the hybrid and the transmitting input of the anti-singing device. That is on the noise level at the hybrid four-wire output and the strength of the trunk speaker. The noise level on that side of the hybrid will again depend on the hybrid balance, the level of received speech sent to the trunk and the signal to noise ratio. So that the degree of balance becomes more important with weak speakers, poor hybrid balance, high received speech level to the trunk and low received signal to noise ratio.

It should be noted that while the anti-singing device is protected against false operation on received noise by the differential arrangement, it is protected against false operation by noise from the trunk solely by the frequency discrimination of the A.S.D. circuits.

In conclusion, it should be mentioned that the foregoing remarks are concerned with the conditions for establishing the transmitting path. Once this path is established, the receiving suppressor repeater is paralysed and received noise is therefore absent from the anti-singing device.

(To be continued)

MARCONI NEWS AND NOTES

MARCONI-E.M.I. TELEVISION COMPANY, LTD.

A NEW company was registered on May 22nd under the name Marconi-E.M.I. Television Company Limited.

The shares are held equally by the Marconi Company and Electric and Musical Industries Limited. The new company is the result of an agreement between the Marconi Company and Electric and Musical Industries Limited to form a television merger on a fifty-fifty basis. The agreement relates to high definition television. The Board of the new company will include His Excellency the Marchese Marconi, The Right Honourable Lord Inverforth (Chairman of the Marconi Company), Mr. Alfred Clark (Chairman of E.M.I.), and the Managing Directors of the Marconi Company and E.M.I. respectively.

Lord Inverforth has accepted an invitation to be Chairman of the Board.

In the Forefront of Development.

Speaking of the new television company at the annual meeting of the Marconi Company on May 23rd, Lord Inverforth said :—

"We are in the forefront of television development. Following a careful examination of the television research done by other companies at home and abroad, we have decided to combine with Electric and Musical Industries Limited, to pool our resources in high definition television transmission and to form a new company for the production of those types of television transmitters for which we foresee the greatest opportunities in the broadcasting services of the world. Two transmitters manufactured at our Chelmsford works have been used experimentally for more than two years. The research laboratories of the Marconi Company and of E.M.I. will henceforth combine in that field of television in which we have agreed to collaborate. In fields other than that of high definition television we shall continue to work independently."

Marconi Company's World-Wide Progress.

OTHER points of interest emerging from Lord Inverforth's speech at the annual meeting were that the value of orders received in 1933 was greater than that of the orders obtained in 1932, and that contracts were concluded for the supply of all types of wireless plant, including broadcast transmitters, naval, military, and aircraft apparatus, and telegraph and telephone stations to 45 countries in all parts of the world.

"More than four-fifths of these orders, reckoned in value, were obtained in competition with foreign companies," said Lord Inverforth.

"Our engineers were engaged in erection work in most European countries and in Asia, Africa and South America. In the course of the year we put on the market 21 new types of wireless apparatus to meet the varying demands of our clients. The contract price of manufacturing work in hand on December 31st was £921,000.

"The technical reputation of the Marconi Company has never been higher than it is to-day, and it is our intention to uphold it by maintaining and, if necessary, increasing our expenditure for research work. The Marchese Marconi continues his micro-wave investigations in Italy and on the Mediterranean. The research section which deals with problems of broadcast reception was enlarged at the beginning of the current year. There was increased activity in all our research and development departments. Our broadcasting transmitters embodying the floating carrier system are in ever-increasing demand. In the course of 1933, 720 applications were ordered to be filed and the total number of patents and applications on our books on December 31st was 6,221."

Radio House, Cairo: Headquarters of Egyptian State Broadcasting.

Egyptian State Broadcasting.

BROADCASTING in Egypt was placed on an official basis from May 31st, when the new State Broadcasting Service, operated by the Marconi Company on behalf of the Egyptian Government, was inaugurated.

Two new broadcasting stations have been built to provide a regular and efficient programme service in the most densely populated areas of the country, a high-power installation at Abu Zabal (near Cairo), and a relay transmitter at Ras-el-Tin (near Alexandria).

The stations are connected by land lines with a suite of studios at Radio House, Cairo, the headquarters of the State Broadcasting Service.

All the technical equipment at the stations and studios is of the most modern type, and this newest factor in the cultural development of modern Egypt has behind it the advantage of the fifteen years' accumulated experience of the Marconi Company in the sphere of broadcasting.

At the recent Lucerne Conference two wavelengths were reserved for Cairo and two for Alexandria, but at the outset only one will be used at each city, the Cairo station operating on 483.9 metres and Alexandria relay on 267.4 metres.

Programmes.

About 75 per cent. of the programme time will be devoted to transmissions for the native population and 25 per cent. to matters of interest to the European population, while news will be broadcast in Arabic, French and English. The stations will be at the disposal of the Government for official communications dealing with agricultural and hygiene reports, the level of the Nile, and weather bulletins.

Other special features of the programmes will be lessons in Arabic and foreign languages and the performance of Oriental as well as European music. "Sponsored programmes" will not be accepted.

The Stations.

The Cairo station has an aerial power of 20 kilowatts, with modulation up to 100 per cent. Its frequency response is substantially flat between 30 and 10,000 cycles so that it can do full justice to every type of studio and outside broadcast performance.

The station at Ras-el-Tin, which is to be used as a relay station for the Cairo transmissions, is semi-automatic in its operation. It has a power of 250 watts in the aerial, with modulation up to 80 per cent. The frequency response of this station, like that at Cairo, shows a substantially flat characteristic between 30 and 10,000 cycles, and is thus of equally high performance. Although Ras-el-Tin station is required to serve a limited area only, its design follows in principle that of the most modern high-power transmitters and equal care is exercised to provide for exact stabilisation of the transmitted wave, a high precision quartz crystal being used.

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