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FEEDER ADJUSTMENTS FOR SHORT WAVE VERTICAL AERIALS

The following notes are written to assist those who are concerned with the erection of omni-vertical aerials and the subsequent connection to feeder lines. It is hoped at a later date to give further notes in connection with beam aerials and feeders generally.

The present problem is one of matching the impedance at the base of an aerial to the natural or surge impedance of a particular form of feeder, the Marconi Concentric type.

As a preliminary it will be useful to study an aerial with reference to equivalent load resistance.

If Fig. 1 represents a vertical length of wire, let us say slightly less than ten metres long with its lower tip about six feet above ground, it may be taken to indicate a 20 metre half wave vertical aerial which under suitable influence would oscillate in such a manner that the current and voltage distributions are as per the dotted and thin line curves. In order to maintain any particular intensity of radiation it is necessary to feed it with H.F. current such that the current multiplied by the potential at the point of feeding equals power radiated. Since a resistance can always be found such that $R \times I^2 = I \times E =$ power, it is convenient to define the radiating property of an aerial in terms of a resistance, and it is usual to define the radiation resistance of a half wave aerial such that :—

$$R \text{ (radiation)} \times I^2_{max.} = \text{power radiated.}$$

Where " I " is the maximum R.M.S. current, i.e., the R.M.S. current at the centre of the aerial. This resistance equals the equivalent load resistance of the aerial were it possible to feed it at its geometric centre ; *it is thus a fictitious value* but is very useful as affording some idea of the relative radiating properties of various aerials. The rough figure for a half wave aerial varies between 120 and 80 ohms, the latter being for an aerial well above ground while the former is for an aerial close to the ground where absorption is great and the useful radiation perhaps not more than 20 per cent.

The other value of resistance, and the one that now concerns us more closely is such that—

$$E^2 \text{ max.}/R = \text{power radiated}$$

where $E_{max.}$ is the maximum R.M.S. voltage between earth and the lower tip of the half wave element. (To be logical this might equally well be written $R \times I^2_{min.}$ where $I_{min.}$ is the minimum R.M.S. current, which can conveniently be regarded as the space current about the tip of the aerial). Let us call the equivalent load of the aerial when fed in this way " R base " : this will vary with the overall height of the aerial measured in wavelengths and for the half wave element with lower tip about six feet above ground may be of the order of 2,000 ohms. If the half wave element is replaced by a higher one the value drops and, as the height increases, tends towards a constant figure of perhaps 600 ohms. This " R base " might be called the " aerial base resistance " and is the value that interests us at present since it indicates the nature of our problem, viz., how to match a base resistance varying between 2,000 and 600 ohms to a feeder whose correct termination should be equivalent to about 75 ohms.

Half Wave Vertical Aerial.

Taking first the case of a simple half wave aerial, the practice is to erect the element with its base anchored and insulated about 6 feet above ground level, and from the base end to run a horizontal tail to the aerial transformer box, the tail being usually about one-eighth wavelength long ; thus the aerial together with its tail, tuning coil, and lead from box to ground totals approximately three-quarters of a wavelength and enters the ground at a point of no potential. In Fig. 2, Sketch (A) indicates the actual run of the aerial with its coil and earth leads ; while Sketch (B) indicates the equivalent plain straight wire.

Since the lower quarter wavelength is composed mainly of a low horizontal wire and a coil it will be regarded as non-radiating and may therefore be replaced, figuratively and without violating principles, by a closed circuit as per Sketch (C) of Fig. 2, in which " L2 " represents the equivalent inductance of the quarter wave element and " C2 " its *effective* capacity to earth. This combination will oscillate to the natural frequency of the vertical half wave aerial because while " L2 " is only half the inductance of the latter, " C2 " is twice the effective capacity, since in one case the capacity is between the upper and lower sections of the half wave element while in the other case the capacity is between one such section and earth, or neutral.

We have now an open half wave element coupled to a closed circuit in tune with it ; owing to the direct coupling the load due to radiation will be thrown into the closed circuit and in fact may be represented by a series resistance " R " equal to the radiation resistance of the half wave aerial. But, from the theory of tuned circuits, we know that, at tune point, the closed circuit is equivalent to a pure resistance—

$$(\omega L_2)^2/R$$

This is the aerial base resistance and therefore the equation gives the relation between the aerial base resistance and the aerial radiation resistance: if we prefer the equation in terms of L, the inductance of the half wave aerial, then since L_2 equals half L the base resistance equals:—

$$(\omega L)^2/4R$$

Next, let us consider how to couple up this base circuit to the feeder that is energising it, in other words, how to transform the base resistance into R_O, the surge impedance of the feeder. Obviously the thing to do is to tap the feeder some way up the base inductance, but unfortunately this does not yield the simple transformer effect desired because of the two circuits which comprise the transformer only one, the aerial circuit, is tuned; the other consists of perhaps one or more turns of coil unbalanced by any capacity, i.e., it is untuned. Thus, though the ratio of aerial coil turns to feeder tap turns may be such as would give the correct ratio between R_O and R_B, the feeder tap is an unbalanced inductance and will make the load thrown on to the feeder quite inductive, whereas it must be purely resistive. The problem is how to make the feeder load non-inductive. For simplicity let us, as in Fig. 3, indicate the feeder tap as a separate coil or loop with a coupling of mutual inductance to the aerial base coil, then adopting the symbols of Fig. 3 and assuming the far end of the feeder to be connected to a source of high frequency power, let us trace the coupling reactions.

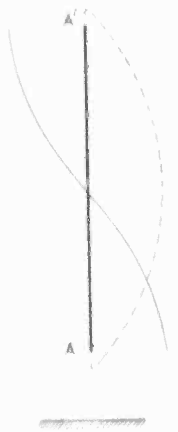

FIG. 1.

Inductively Coupled Circuits.

Assuming the aerial base circuit to be in tune with the aerial it is equivalent to a pure resistance that we have termed "R base"; again we have the feeder terminating in a simple coil whose inductance is not neutralised. After coupling one to the other by an appropriate number of turns we might insert a series capacity to balance the feeder coil inductance, see (B) of Fig. 3, but such a procedure is not very practical and so we must devise some other means.

We know from the theory of tuned circuits that for a given value of inductance, capacity and resistance, the characteristics of the circuit vary as the frequency; thus as the frequency of the applied E.M.F. approaches, coincides with and exceeds the natural frequency of the circuit, so the equivalent resistance (as measured between A and E of Fig. 3) rises rapidly, reaches a maximum and falls again towards some approximately constant value. Also for frequencies lower than the natural frequency of the circuit the reactance is capacitative, while for frequencies higher than natural frequency the reactance is inductive.

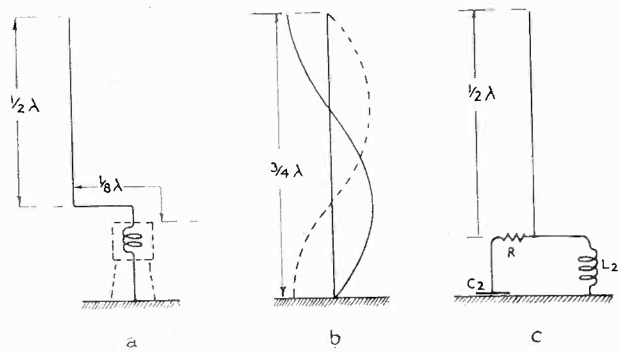

FIG. 2.

To understand the coupling reactions, between the feeder loop and the aerial base circuit, let us examine the characteristics of the latter. In Fig. 4 the curve (1) indicates inductive reaction, curve (2) indicates capacitative reaction, curve (3) indicates the combined result of these two components, while curve (4) gives roughly the resistance component. When the frequency is "n," the natural frequency of the aerial, the two reactions are equal and opposite and the circuit exhibits only a pure resistive effect, but on either side of "n" there is a reactance component which is capacitative or inductive according as the frequency is lower or higher than "n." If, however, the circuit is detuned by increasing either the capacity or the inductance it is apparent from Figs. 5(A) and 5(B) that *the reaction at "n" is inductive*. Leaving it inductive, we will trace the relations between feeder-loop and circuit. An E.M.F. from the feeder coil induces a current in the circuit which has a resistive component in quadrature with the E.M.F., and also, since the circuit is inductive, a reactance component which must be in quadrature with the resistance component, and therefore one hundred and eighty degrees ahead of the E.M.F.

Both components couple back on to the feeder loop, but for the moment that which interests us is the reactive component, which induces a current in quadrature with itself and therefore 180° plus 90° ahead of the feeder E.M.F.

To sum up, the total effect of the inductive reactance in the circuit when coupled back on to the feeder loop has been to induce a current in the loop 270° ahead of the feeder E.M.F. ; but this is equivalent to a current leading by 90°, in other words, to a capacity current in the feeder loop. The effect, then, of detuning the aerial base circuit to a lower frequency is to throw back into the feeder loop a certain amount of capacity reaction. By careful adjustment it is possible to take advantage of this effect and balance out the induction of the loop itself, leaving the resistance component as the nett result of the coupling. So far little has been said about this resistance component, which, after all, is the main objective, but it must be already apparent that when we change the tune of the aerial base circuit the resistance curve alters appreciably from curve (4) in Fig. 3(A) and flattens out ; it is unnecessary to go more deeply into the analysis since it is clear that the feeder tap, i.e., the amount of coupling, now appropriate for the termination of a Marconi Concentric Feeder, differs appreciably from the tap that would have been suitable had the aerial base circuit been in tune.

The simplest method of detuning is to increase the aerial coil turns, and this explains why the turns in the aerial coil are generally more than called for if it were a simple case of tuning. When the available aerial turns appear to be too few, another method is to detune with additional capacity across the aerial coil, by means

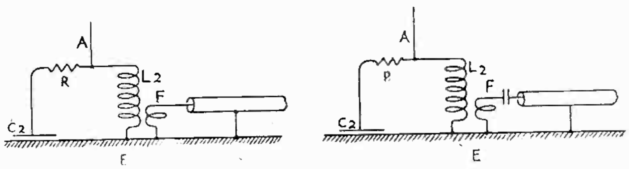

FIG. 3.

of a length of feeder tube as indicated in Fig. 4, but this is a method seldom adopted, although it appears to be suitable for all receiving aerials. Unless on low power the device may not be suitable for transmitting aerials because of the possibility of high potentials and the risk of sparking, all the same, under suitable conditions it is helpful.

High Aerials.

We will next take the case of vertical aerials that are higher than half a wavelength, more particularly those built on the " Uniform " principle ; before, however, examining the practical aspect of appropriate feeder adjustments it is necessary to understand the precise difference between a low aerial and one that may extend to a height of two wavelengths, or even more. To obtain the full benefits of height, radiation should not vary in either sign or intensity along the length of the aerial, at any rate to well within a quarter wave of the ground ; in other words, the sign of aerial current should be constant, while its distribution should be practically uniform throughout the effective length of the aerial.

Were it possible to extend the height of an aerial by simply piling up one half wave element on top of another the non-uniform or sine form of current distribution would be perfectly satisfactory, but after considerable experience it has been proved that loss of efficiency follows even the most careful systems of maintaining uni-phase sine current distribution. It is true that harmonic aerials are sometimes employed, but, owing to the natural current distribution of plus and minus signs, this type radiates at a high angle and is most inefficient and prone to interference for any but certain special requirements. Thus, while uniform current distribution has no advantages over sine distribution for low aerials, that is, the simple half wave element would be as efficient as a half wavelength high uniform-current aerial, were such possible, yet when conditions call for the use of high aerials the Marconi uniform system is far and away the best method devised.

Advantages of High Aerials.

Were it only a matter of avoiding ground losses it would be quite practical to raise a complete half wave element well above ground level, connecting it through some known form of feeder, and thus ensure almost 100 per cent. effective radiation. But while this is certainly one factor, there are two other important factors that bear on the quality of transmission or reception. The first is that as the overall height

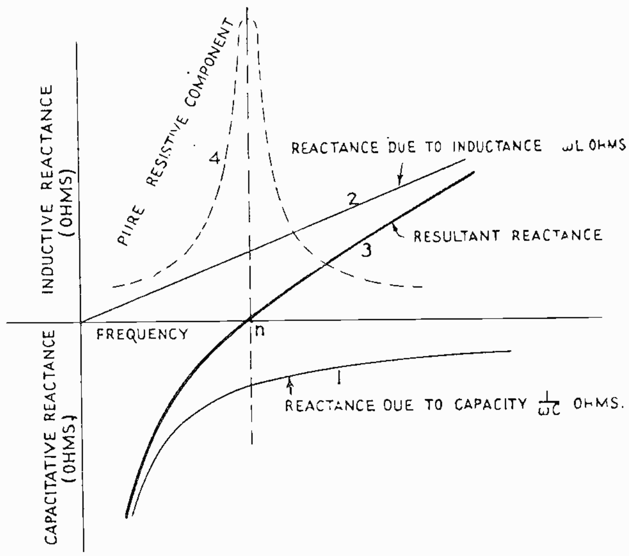

FIG. 4.

in wavelength measurement is increased, so the angle of total emission in the vertical plane becomes narrower and the main stream of energy more concentrated, thus not only is there gain of magnification in the required direction, but the transmission or reception in respect of unwanted directions becomes highly attenuated: this advantage amounts to "signal selectivity" and is very important when it has relation to unwanted out-of-phase signals of the same frequency as the message, a situation with which no known form of receiver can cope.

The second factor applies only to the Marconi Uniform Aerial. This design lends itself to a control of the upward tilt of the direction in which the main stream of energy leaves or enters the aerial, a facility that has proved to be of very practical advantage on many services.

It might be argued still that for a given available mast height it is better to sling up a half wave element and thus raise the centre of the aerial by the maximum possible amount, but apart from the supreme advantage of selectivity gained by actually extending the height of the aerial, a moment's consideration will disclose that in any case the upward tilt and the magnification more than compensate for any difference in average height.

On the other hand, it should not be overlooked that, even in those rare cases where the cost of high masts is not a prime consideration, it is not practical to extend an aerial by more than two wavelengths because of reflection effects, hence, where more than the limiting height is available, the practice is to design an aerial

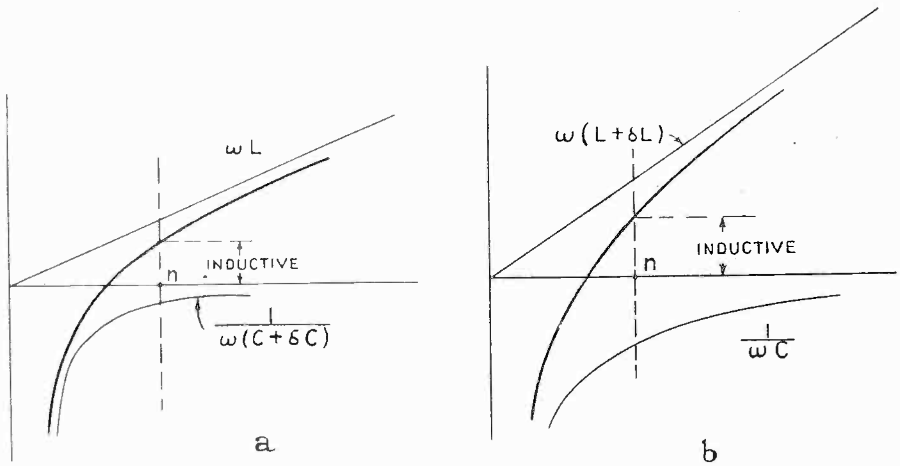

FIG. 5.

extending to one-and-a-half or two wavelengths, and to raise the complete unit above ground, connecting it to the ground feeder through a length of Marconi non-radiating aerial feeder.

Adjustment of High Aerial Feeders.

Purely from the point of view of transformer adjustments, the effect of height and of a uniform build of aerial is that, with the consequent increase of radiation resistance, there is a corresponding decrease of base resistance. (It should be fairly obvious that this is so, since if we flatten out the current there must also be a flattening out of potential ; hence the potential between the lower tip of the aerial and earth has diminished, hence also a diminution in the " base resistance.")

The value now tends towards 600 ohms as compared with the 2,000 or 2,500 ohms value for the equivalent base resistance of a half wave aerial. At first sight this condition may appear easier to handle, because it would seem a simpler proposition to transform down to 75 ohms from a 600 ohms circuit than from a 2,000 ohms circuit, but unfortunately the actual transformation is more difficult. This is explained by the flattening of reaction, in fact reaction is being swamped by an increase in the radiation resistance and it has become very difficult to determine when the aerial base coil is in tune, let alone any subsequent question of adjustments. Thus, if there is difficulty in tuning, there is still more difficulty in detuning sufficiently to exhibit any marked inductive reaction, and we might almost pile up turns in the aerial coil indefinitely and still not have enough reaction to cancel out the feeder loop inductance.

In this case there are, roughly, four courses open :—

(A) A series of fortuitous factors may lead to a satisfactory balance between aerial turns and feeder loop with very little trouble.

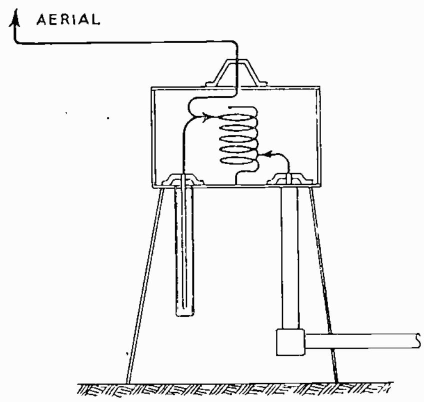

FIG. 6.

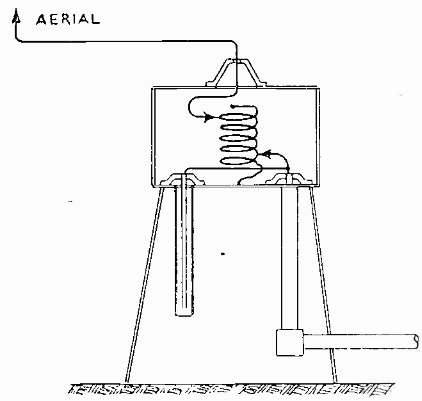

FIG. 7.

(B) The method indicated by Fig. 6 may sometimes be employed with advantage on receiver aerials, and also on low power transmitter aerials, since with high aerials the voltages will be fairly low.

(C) The length of the aerial tail may be varied, with the hope of finding a fairly reactive point to connect on to the aerial coil, thus sharpening up the effect of varying turns in the latter.

(D) Finally advantage may be taken of the following relationship between inductance and resistance in parallel, and inductance and resistance in series. If at any particular frequency the reactance of an inductance L_0 measures R_0 in ohms, then L_0 in parallel with a resistance of R_0 ohms is equivalent to half L_0 in series with half R_0. It follows that if the feeder is loaded up to half R_0, by an appropriate tap whose inductive reaction is half L_0 then the conditions in the feeder terminal loop give half R_0 in series with half L_0 ; but this is equivalent to R_0 in parallel with L_0. Hence if L_0 is neutralised by means of a parallel capacity, we are left with a pure resistance load R_0 on the feeder. Remembering that one-eighth wavelength of feeder has a capacity reaction equivalent to R_0 it will be realised that this method is a practical one, since a length of feeder can be inserted as shown in Fig. 7.

It will be appreciated that in principle the method calls for no detuning, since we are no longer concerned with neutralising the feeder loop by reactive coupling effects but are simply concerned with throwing into the feeder a load equivalent to half R_0. This is a fairly simple proposition calling for a tuned aerial circuit and a weak coupling.

Objection may be raised on the grounds that it is unlikely we shall obtain a tap whose inductive reaction is half L_0 when the coupling effect of the tap just gives half R_0, but, as a matter of experience, under tune conditions and within the rather wide limits of our approximations, load coupling and inductive reaction have a certain fortunate parity.

In practice the method is adopted when it becomes apparent that to get anywhere near the desired adjustment the feeder tap turns are mounting unduly. It is largely a matter of compromise, which means that it is seldom expedient to insert the generally fairly long length of feeder (one-eight wavelength) whose capacity reaction equals 75 ohms, but even a limited application of the principle may give the desired results.

In conclusion the following notes are given as of general interest in connection with aerials.

There are three simple formulæ relating to closed tuned circuits, in which the capacity and inductance is concentrated into two separate elements, that are applicable to an open *tuned* circuit or aerial, in which capacity and inductance is distributed and generally measured as so much per centimètre run of aerial wire. Since the fact of distribution calls for some readjustment of our perspective when defining the constants, it may help if we briefly review the definitions before applying the formulæ.

Effective Aerial Capacity.

From the potential distribution shown in Fig. 1, it is clear that the charge oscillates from tip to tip and therefore the capacity is that of one-half of the aerial with respect to the other, that is, the capacity to space of one-half is in series with the capacity to space of the other half. But two equal capacities in series are equivalent to one-half of the single capacity, thus the effective capacity is one-half the capacity of half the aerial. If C signifies effective capacity and C^1 the total or static capacity, then $C=\frac{1}{4}C^1$.

Owing to the sine form current and voltage distribution we should multiply C by $\frac{2}{\pi}$, but the form factor will cancel out of the equations and therefore does not appear below.

Base Voltage.

It is obvious that the maximum voltage of an aerial is across the ends, therefore the voltage of one end to earth is half the maximum voltage.

Surge Impedance.

The surge impedance of a conducting system may be measured by the formula $Z_0 = \sqrt{\frac{L}{C}}$ where L and C are the distributed inductance and capacity per unit length of conductor. In the case of an aerial the conducting system may be regarded as a single wire of finite length and the ratio of total inductance to total capacity is the same as the ratio of inductance per unit length to capacity per unit length.

Bearing the above relationship in mind we can apply the three well-known formulæ :—

$$\text{Power} = R\,I^2 = V^2/R \quad \ldots \quad (1)$$
$$\text{Power} = \tfrac{1}{2}L\,I^2 = \tfrac{1}{2}\,C\,V^2 \quad \ldots \quad (2)$$
$$\text{Angular Velocity } W = 1/\sqrt{LC} \quad \ldots \quad (3)$$

where I may be taken as maximum R.M.S. current, V the maximum R.M.S. voltage, L total inductance and C the effective capacity.

When applied to an aerial we write :—

$$R\ \text{radiation} \times I^2 = V^2/4 \times R\ \text{base}$$
$$LI^2 = C^1V^2/4$$
$$\omega^2 = 4/LC^1$$

from which we can obtain

$$R\ \text{base} = \omega^2L^2/4R\ \text{radiation}.$$

Obviously as we increase the height of the aerial R_R increases and therefore R_B decreases. (Note that L remains constant, since the frequency is constant and therefore the effective inductance is still that of the half wave element.) In the limit R_R equals R_B and we have

$$R^2 = \omega^2L^2/4 = L/C^1$$

therefore $R = \sqrt{L/C^1}$. But this is the surge impedance of the aerial ; hence as we extend the height of the aerial, the terminal resistance tends to coincide in value with the radiation resistance and both tend to coincide with the surge impedance of the aerial wire.

The surge impedance of No. 14 wire about 12 metres above earth is 600 ohms and this may be regarded as a rough general figure for the surge impedance of an aerial, hence in the limit a high uniform aerial may be regarded as a feeder with radiation acting as distributed resistance and possessing surge or terminal impedance of 600 ohms value.

N. Wells.

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A GRAPHICAL SYNTHESIS OF AERIAL ARRAYS

The following article describes a simple method of calculating graphically the polar diagrams, both in a vertical and horizontal plane, of any array of spaced aerials.

The basis of the method is the combination of two diagrams, both of which are easily constructed from a knowledge of the array constants.

THE approximate theoretical diagram of spaced aerial systems can most easily be worked out by direct mathematical means, such for instance by application of the simple formulæ developed originally by E. Green, but such methods usually assume an infinite number of aerials for convenience, a condition never met with in practice, and the simple mathematical treatment is not suited to all cases.

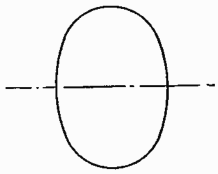
A graphical method of building up such diagrams although involving—initially—the careful plotting of a few " standard " diagrams, gives accurate results, enables one to analyse rapidly any complicated array system, and the method is most useful as illustrating the way in which the final interference pattern is gradually evolved. For the production of " beam " effects by modern aerial systems is not a true reflection problem but is brought about by the interference of the fields from a group of radiating systems having definite positions relative to one another in space.

The graphical method to be described is based on the principle that the complete diagram of any spaced system of unit radiators having the same characteristic, is, the product of what may be called the spacing diagram by the unit diagram. The spacing diagram is that given by two spaced point sources of radiation (circle diagram) and its shape will depend upon their distance apart in terms of the wavelength, and phase of the point sources. The unit diagram on the other hand, is dependent upon the diagram of the sources themselves.

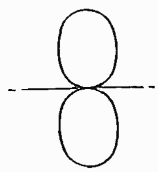
For instance, if the unit sources are frames their diagrams would be figures of eight, if verticals, circles. It is clear that since the unit diagram is a function of the source itself, the position in space is immaterial.

The spacing diagram on the other hand is a function of the interaction of two units and will vary with the phase and position of these units, and as will be shown later its shape is determined by the spacing in terms of the wavelength and phase. With very close spacing, i.e., less than one quarter of a wavelength, there is never very great phase difference between the fields (unless deliberately produced) and hence the polar diagram is nearly circular but as the spacing is increased beyond half a wavelength to many wavelengths, there are positions where the fields cancel, and positions where they add, so that a complex interference pattern is produced. The evolution of such a pattern is shown in Figs. 1, 2, 3 and 4 (shown more accurately in *a*, *b*, *c*, *d*, Fig. 22), which give the polar diagram of two spaced point sources of radiation fed by current in phase, at spacings of $\frac{1}{4}$, $\frac{1}{2}$, 1, $1\frac{1}{2}$ and 2 wavelengths. Observe how the " tails " are sharpened up and more produced as the spacing is increased.

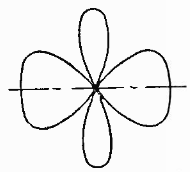
Had the phases of current been 180° apart, the diagrams are changed as shown in Figs. 5, 6 and 7. For wavelengths less than $\frac{1}{2}\lambda$, the diagram is completely changed with change of phase, but with $\frac{1}{2}\lambda$ and greater spacings, the diagram is reversed, not rotated. With phases other than these, the diagrams will change in shape between the two extreme forms shown, but generally speaking one is not often called upon to consider cases of this nature.



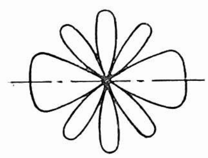
¼ λ
FIG. 1.



½ λ
FIG. 2.



1 λ
FIG. 3.

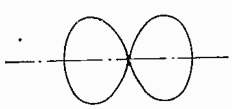


2 λ
FIG. 4.

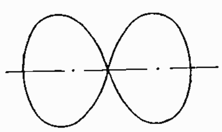
It is of interest to show how the spacing diagram is evolved. Fig. 8 shows two point sources A and B with current in phase, spaced a distance AB = $n\lambda^\circ$ apart in the " *xx* " axis. Thus if AB is half a wavelength spacing the sources are 180° apart. At any angular direction AP, say θ° from the normal to " *xx*," the phase difference between A and B is

$$\Phi^\circ = n\lambda \sin \theta$$

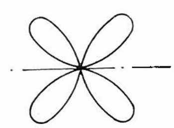
Now the resultant field in any direction AP is the vector sum of the two fields " *a* " and " *b* " whose angular phase difference is seen to be Φ°.



¼ λ
FIG. 5.



½ λ
FIG. 6.



1 λ
FIG. 7.

If we assume the fields " *a* " and " *b* " to be equal (to unity say) the vector sum is OQ Fig. 9.

$$\text{Now} \quad OQ = 2\ OM \text{ and}$$

$$OM = ON \cos \frac{\Phi}{2}$$

$$\text{Thus} \quad OQ = 2b \cos \frac{\Phi}{2}$$

Had the initial phase of currents in A and B not been zero but some angle Ψ, this must be taken into account and the complete expression becomes :—

$$\text{Resultant field OQ} = \Psi \pm b \cos \frac{\Phi}{2}$$

The $\pm$ is necessary as with odd phases, the diagrams become lop-sided due to the reversal of phase sense of the interfering fields as one passes through the 90° position.

With anti-phase currents in "a" and "b" the resultant is the vector difference namely, LN and $LN = 2b \sin \frac{\Phi}{2}$

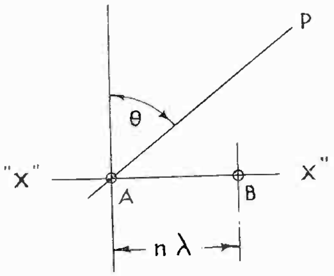


FIG. 8.

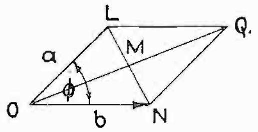


FIG. 9.

An example of misphased currents in two spaced sources is found in the ordinary reflector aerial. Thus consider a single aerial and single reflector spaced one quarter wavelength behind. Their current phase is quadrature and the diagram produced is as shown in Fig. 10 which is seen to be nearly a cardioid. This is the result that would be obtained by two such point sources operating in the above manner and we are not discussing any possible mutual coupling between the sources modifying the diagram. Actually in practice a somewhat greater spacing is found necessary on this account. If one considers a reflector wire spaced three-quarters

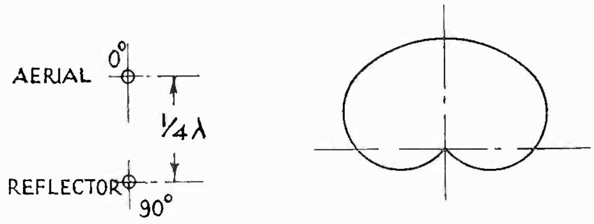


FIG. 10.

of a wavelength behind the aerial, a common setting for the reflectors on the shorter wavelength, the diagram is seen to be quite different. One still gets phase addition forward, and phase opposition behind but the diagram otherwise is quite altered as shown in Fig. 11.

The foregoing may be called "standard" diagrams and they will be used to produce the diagrams of various arrays. For instance consider an array of four aerials each spaced half a wavelength apart, all fed by current in phase, with a similar array acting as a reflector, as shown in Fig. 12, we may visualize each aerial as a unit source of zero phase radiating a circle diagram. Neglecting the reflector and considering sections of the array, we may group 1 and 2 together as a pair, and 3 and 4. But if we take each pair these give the elongated figure eight (standard diagram Fig. 2) at right angles to the array line and thus we could replace the four original single units half a wavelength apart, each giving a circle diagram, by two units one wavelength apart each giving the elongated figure eight.

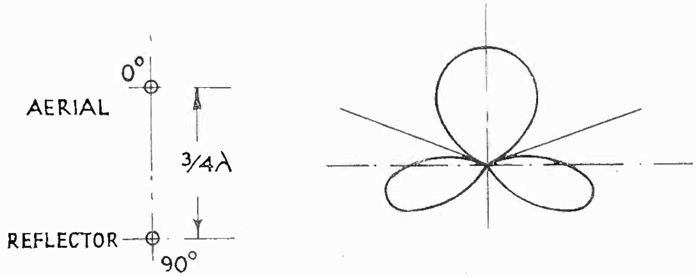


FIG. 11.

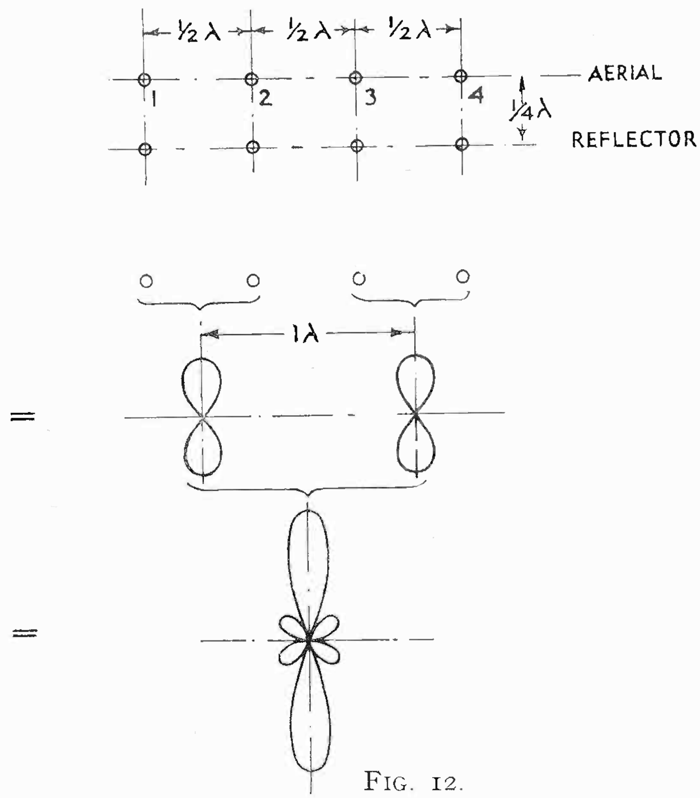


FIG. 12.

Now if we had two circle sources one wavelength apart in phase they would give the standard diagram Fig. 3, by virtue of spacing, but since the sources are not circles, but give the half-wave figure, the total polar diagram is the product of the two (namely, standard diagrams Figs. 3 and 2). The result is to give the bi-directional figure as shown in Fig. 12.

If the reflector is now considered, as this can be assumed, separately, to give a similar polar diagram to the aerial array, but with a quadrature phase of current, and to obtain the total diagram it is only necessary to find the product of the resultant diagram of Fig. 12 with the "standard" reflector diagram Fig. 10 if the spacing is

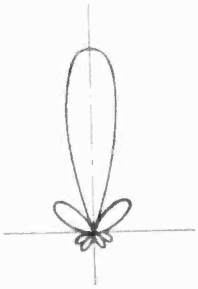


FIG. 13.

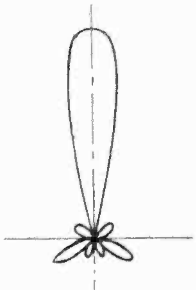


FIG. 14.

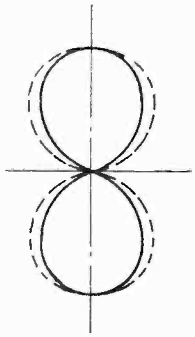


FIG. 15.

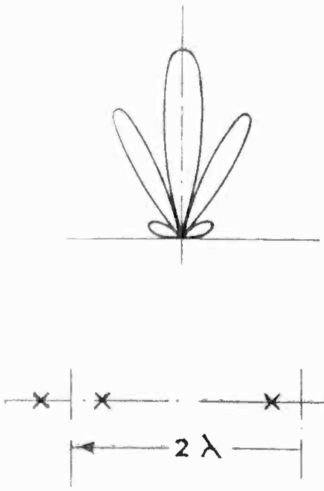


FIG. 16.

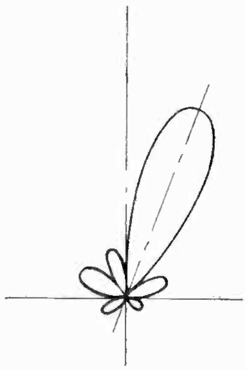


FIG. 17.

one quarter wavelength, and Fig. 11 if three-quarters. The result of each is shown in Figs. 13 and 14 from which we can observe that the former gives a better cut off behind, the latter a better diagram at angles near the array line.

To obtain the diagram of an eight unit array needs but one step from the last array considered, as we have merely to take the product of the 4-array polar diagram and the spacing diagram of two point sources two wavelengths apart (standard diagram Fig. 4). The resultant figure is shown in *h*, Fig. 22.

An interesting case is the difference between close and wide spacing of aerials in an array. For instance what is the gain of using four elements each spaced $\frac{1}{4}\lambda$ as against two elements spaced $\frac{1}{2}\lambda$. The comparison is shown in Fig. 15, where the dotted curve is the two elements spaced $\frac{1}{2}\lambda$ and the full curve the four spaced $\frac{1}{4}\lambda$, from which it is clear the gain is extremely small from the diagram point of view. Actually in practice there is a gain in putting more elements in the space and this is to make the system more flat-tuned so that it can be used for a band of wavelengths, without serious loss of efficiency. The diagram of four elements spaced $\frac{1}{4}\lambda$ apart is found by multiplying the diagram of two units $\frac{1}{4}\lambda$ apart in phase (standard diagram Fig. 1) with the $\frac{1}{2}\lambda$ diagram.

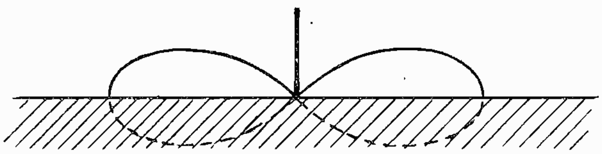


FIG. 18.

By changing phases and spacing a large variety of diagrams can be produced but in general the number of minima and maxima will depend on spacing, in every quadrant one minimum and one tail for every wavelength spacing with one additional maximum (or minimum) depending upon phase. The changing of phase merely alters the relative shape of these tails and their angular position.

If two or three main tails for radiating to stations away from a line normal to the line xx are required we can "split" the diagram in a variety of ways, either by changing the phase of current in each unit, or by using pairs of aerials with wide spacing, an example of the latter being shown in Fig. 16 which gives the diagram of two pairs of elements each half-wave apart spaced two wavelengths.

In practice, to divert a train beam a few degrees, is done by making a small phase shift of each aerial such that the fields add in the desired direction. For instance consider a shift of main beam of 10 degrees with a four element array. This will require a phase shift of 30° per element with half-wave spacing, and the resulting diagram is shown in Fig. 17.

It is now proposed to deal with the zenithal diagram of aerial systems, and in general all aerials are to be considered as made up of elementary radiating pieces of very short length through which passes uniform current.

An elementary length of wire in free space with uniform current radiates a maximum at right angles to its length (proportional to the current passing) and zero in line, and the complete diagram is a cosine considered from a plane normal to the length.

An aerial is made up of a number of such elementary lengths, the radiation being greatest at those points where the current is greatest and up to a length of wire $l = \frac{\lambda}{2}$, all sections of the aerial assist to produce radiation in the same phase.

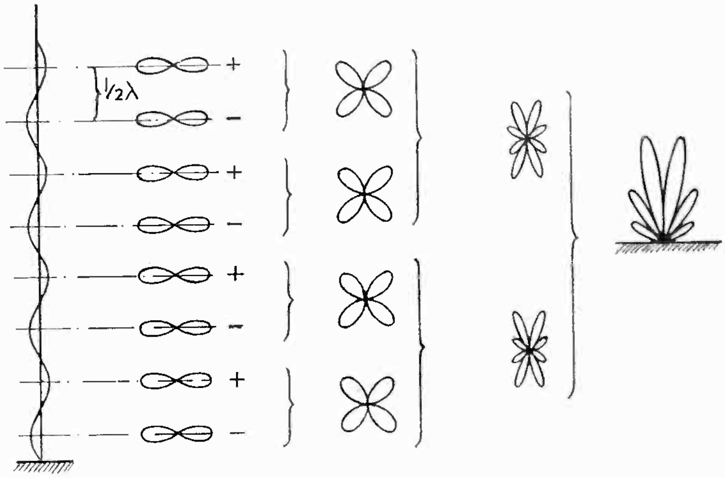


FIG. 19.

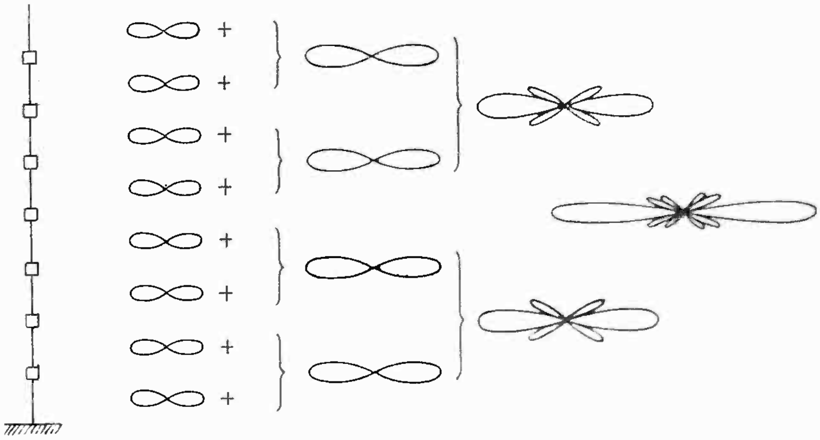


FIG. 20.

Because of the now, non-uniformities of current and the length, the shape of the polar diagram is no longer a cosine but almost a cosine[1], shown in Fig. 18.

If the effect of a conducting earth is considered this cuts off half the diagram and if the earth is a bad conductor more than half will be cut off.

Thus we can consider any aerial whose length is long compared to the wave-length, such as all short wave aerials, as made up of a series of point sources, one for every half wavelength of wire, each radiating a cosine^3 diagram with a phase dependent upon the type of aerial used. For instance consider a harmonic aerial of say 4-wavelengths long, as shown in Fig. 19. This may be considered as made up of 8 units spaced $\frac{1}{2}\lambda$ apart, with alternate phase of current in each. Each unit radiates a cos^3 diagram and thus for each pair of half wavelengths of wire, we have the product of a cos^3 diagram with the $\frac{1}{2}\lambda$ out of phase diagram.

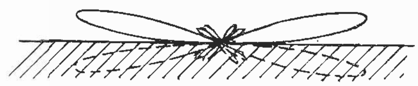


FIG. 21.

Each pair can now be combined by the last diagram and standard 1λ in phase diagram and so on and the final figure is as shown in 19 where the image has been omitted as cancelled by earth. Actually the diagram is not strictly correct, as a conducting earth would not hold for the waves used on harmonic aerials, but this can be allowed for by a modification of the original cos^3 diagram, adopting Eckersley's theorem of antiphase images. But where the diagram is giving high angle radiating such as this, the difference is too small to be observed, as the anti-phase image theorem is only correct for angles up to the critical value, which for all waves is low.

If an aerial with phasing units is considered similar grouping is obtained except the first products are obtained with *in phase* diagrams and this entirely changes the final result as is seen by studying Fig. 20. Here the conducting earth does not give a true picture of affairs except for the upper part of the diagram and the diagram of 21 is the result of taking the effect of a bad conducting earth into consideration.

Other interesting cases are the non-radiating Franklin single wire feeders, which can be regarded as series of half wave aerials doubled up into spacings of quarter-wave or less ; and the harmonic aerial and attendant reflector, erected at a shallow angle to the ground to " project a tail " at the required shallow angle, but these will be left for the reader to produce.

A. W. LADNER.

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

(PART 1)

It is well known that it is possible in a case of circuits arranged as for either parallel or series resonance to adjust the values of the resistances of the capacity and inductance in such a manner that the total impedance measured across the circuit is real and constant for all frequencies.

This condition is applied in what follows to the design of attenuation and phase correcting networks.

CONSIDER the combination of resistances capacities and inductances shown in Figs. 1A and 1B. The impedance between the points 0 and 2 is at all frequencies equal to R if the inductance L and the condenser C be so chosen that $\sqrt{\frac{L}{C}} = R$. The mathematical proof of this can be quite easily developed, either by the use of orthodox circuit analysis or by the circle diagram as used by Professor Mallet and others. The latter method is followed here as a construction leads to useful extensions of wide application.

Referring to Fig. 1A the total impedance across 0—2 is the vector sum of the two impedances 0—1 and 1—2. Now, to find the impedance of these two sections 0—1 and 1—2 it is necessary to add the admittances of the parallel elements in each section in order to obtain the total admittance, and the impedance of the sections is then found by taking the reciprocal of the total admittance. The two impedances 0—1 and 1—2, are then added vectorially to obtain the total impedance 0—2.

Fig. 2 illustrates the graphical construction by which this can be done. It is essentially a vector diagram of which the point O is the origin. On OC as diameter a circle OA′AFCE′EG is drawn. From the extremity of the diameter C a tangent DD′CBB′ is drawn (perpendicular thereto). Now the triangles OA′C and OB′C are similar,

$$\therefore \frac{OA'}{OC} = \frac{OC}{OB'}$$

$$\therefore OA' \times OB' = OC^2.$$

Similarly OA × OB, OE′ × OD′ and OE × OD are each equal to OC^2. Now with given values of L and C (it is of course understood that these must fulfil the condition that $R = \sqrt{\frac{L}{C}}$) a frequency f_q (termed the "quadrantal frequency") is chosen so as to make the admittance of the inductance and condenser elements each equal to that of the resistance elements, i.e., $\dfrac{j}{w_qL} = jw_qC = \dfrac{1}{R}$ or

$$w_q = 2\pi f_q = \frac{1}{\sqrt{LC}}$$

Now in the diagram CD at right angles to OC downwards and of the same length

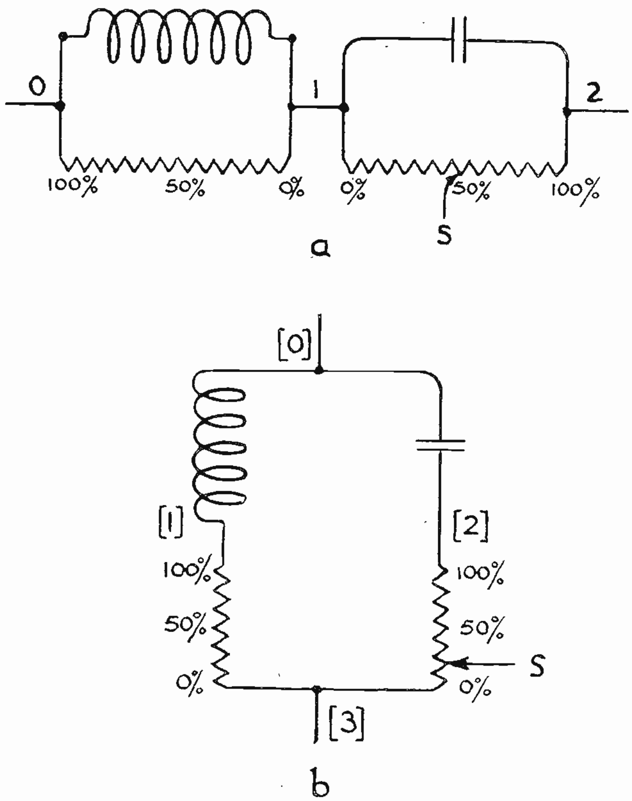


FIG. 1.

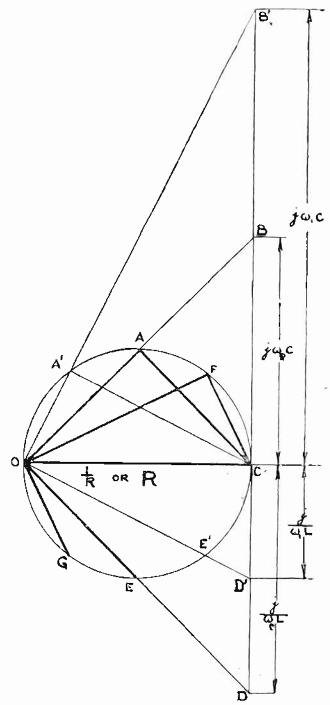


FIG. 2.

represents $\dfrac{j}{w_qL}$ and similarly CB represents jw_qC. Now it is clear that OD the vector sum of OC and CD represents the total admittance of the inductance and resistance in parallel. Now $OE \times OD = OC^2$

$$\therefore\ OE = \frac{OC^2}{OD} \text{ or } \frac{1}{OD} = \frac{OE}{OC^2}.$$

Now as OC has been made equal to $\dfrac{1}{R}$, $\dfrac{1}{OC^2}$ will be equal to R^2 and $\dfrac{1}{OD}$ will be equal to OE $\times$ R^2. Thus the impedance 0—1 may numerically be represented by the length of the line OE multiplied by the constant R^2. As inversion of a vector involves changing the sign of its angle it will be found that the vector may be completely represented by R^2 times a line of the same length as OE and making the same angle with the diameter OC but in the opposite semi-circle, i.e., by $R^2 \times$ OA. Similarly the impedance of the capacity section 1—2 may be represented by $R^2 \times$ OE. The vector sum of OA and OE is OA plus AC and is equal to OC, and it will therefore be found that R^2 times OC represents the total impedance 0—2. Now OC has been made to represent $\frac{1}{R}$, therefore the impedance 0—2 is equal to $R^2 \times \frac{1}{R}$, or R. The construction is also shown for a frequency twice the quadrantal frequency at which the inductive admittance CD′ has halved whilst the capacitative admittance CB′ has doubled. The impedance 0—1 is then represented by R^2 times OF and that of 1—2 by OG$\times R^2$ the vector sum of the two being R^2 times OC, or R, as before. Similar constructions may be applied to any and all frequencies and will show that the total impedance is, for the values of C, L, and R defined above, non-reactive and equal to R. A closely similar construction applies to the case shown in Fig. 1B. In this case the total impedance of each branch limb has first of all to be found. These then have to be inverted into admittances and added. The nett result is that the vector OC is first made to represent a resistance R, and the construction finally shows that it also represents the admittance [0]—[3] as a pure conductance $\frac{1}{R}$. Thus it establishes the fact that the impedance [0]—[3] as in the other case is at all frequencies a resistance R.

Further consideration will show that for the case of Fig. 1A the circle in Fig. 2 may be regarded as a locus diagram. The top semi-circle indicates the locus of the impedance 0—1, the bottom semi-circle that of the impedance 2—1. For the top semi-circle, the impedance 0—1 is obviously zero at zero frequency and becomes R at infinite frequency. In the case of the bottom semi-circle the impedance 2—1 is R at zero frequency dropping to zero at infinite frequency. In both cases the rotation of the locus point is anti-clockwise as the frequency is increased. Similarly referring to Fig. 1B the top semi-circle (again treating point O as the origin) is the locus of the admittance of the limb [0]—[2]—[3] starting from o as zero frequency, whilst the lower semi-circle is that of the inductive limb C being zero, [0]—[1]—[3], and O infinite frequency. In both cases again the rotation of the locus point is anti-clockwise as the frequency is increased.

In making the construction the term "quadrantal frequency" was used. It is clear from an inspection of the diagram that at this frequency the vector OA is in quadrature to AC for the upper semi-circle case, and similarly OE and EC are in quadrature for the other semi-circle, hence the term "quadrantal frequency."

In Fig. 3 is shown an extension of the construction which may be interpreted in the following manner. The circle OA′AFCE′EG corresponds with the circle in Fig. 2. The lines drawn from C refer to frequencies, which are marked where they cut the outside circle, and they only refer to the case illustrated, where for

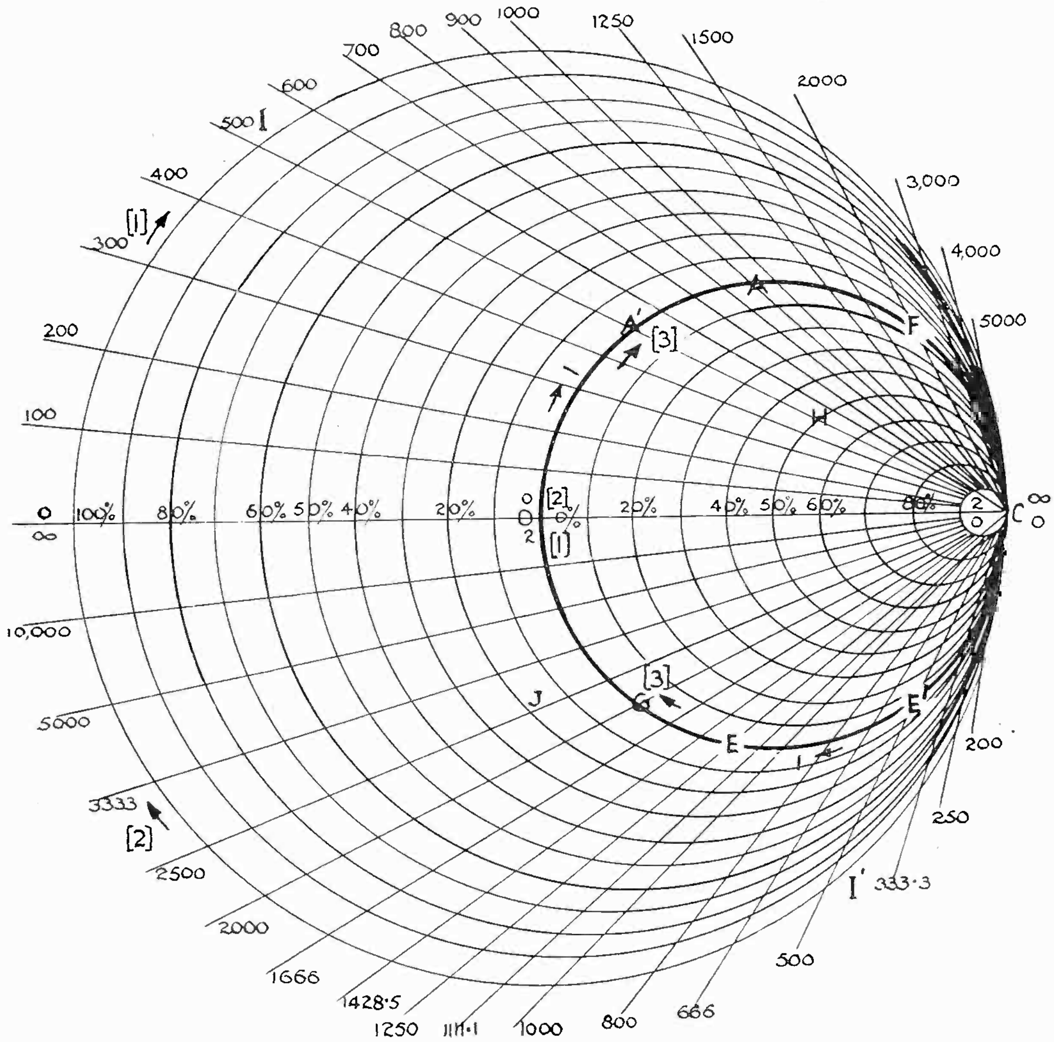


FIG. 3.

simplicity a quadrantal frequency of 1,000 cycles has been chosen. The meaning of the other circles, which it will be noticed are all mutually tangential at point C will now be explained. Considering Fig. 1A, the vector OC represents the impedance 0—2, and the semi-cricle OA′AFC is the locus of the impedance 0—1. Now imagine the resistance between 1 and 2 converted into a potentiometer the relative distances from the ends being considered in the manner indicated. Now suppose the tapping point or slider was fixed half-way along or at 50 per cent., how can we find at any frequency the vector potential 0—S ?

Now Fig. 3 can be interpreted as a diagram from which the relative potential between any two points may be read off. The numbers in ordinary type refer to the conditions for 1A, those inside square brackets for those of 1B. In the former case those just above the main diameter refer to that diameter but for the conditions of the top semi-circle, while those just below it similarly refer to the conditions appropriate to the bottom semi-circle. The numbers adjacent to arrows refer to a movable locus point, its position at any frequency being defined by the lines radiating from C. Thus, for example, at a frequency of 500 cycles, if OC or 02 represents the potential 0—2, the potential 0—1 may be found by joining O with the place where the locus 0—1 cuts the 500 cycles line, or A′. Similarly A′C for the same frequency represents the potential 1—2. Now when the slider S is half-way along the resistance between 1 and 2 it is clear that its potential may be found by going half-way down the vector A′C to point H. If this construction be carried out for other frequencies it will be found that the locus of the potential S when S is placed 50 per cent. along the resistance, is the small top semi-circle marked 50 per cent. The potential 0—S may then be found by joining O with the intersection of the appropriate frequency line with this semi-circle. Similarly for any other position of the slider the locus can be found by drawing a semi-circle in the correct relative position. A series of circles inside the main circle and co-diametrical with OC and tangential at C may then be said completely to represent vectorially the potential between any two points in the system of Fig. 1A.

The conditions of Fig. 1B have to be rather differently considered. Now for a given applied E.M.F. between [0] and [3], the currents in the limbs [0][1][3] and [0][2][3] are just proportional to the admittances of these limbs. Again the vector potentials [3]—[1] and [3]—[2] are the products of these currents multiplied by the resistances. These potentials may then be represented by the corresponding admittance vectors for the respective limbs. A little consideration will show that on the same scale as these vectors represent the potentials, the line OC represents the applied E.M.F. across [0]—[3]. There are several ways in which the diagram can be applied to the conditions of 1B, but perhaps the most interesting is the one given below. At infinite frequency the potential [2]—[3] will equal the applied potential [0]—[3] and it will diminish to zero at zero frequency. The top semi-circle will be found to represent the locus of the potential [2]—[3], [2] being the origin O and [3] the point on the semi-circle, which moves anti-clockwise from O as the frequency increases. Similarly the bottom semi-circle is the locus of the potential of [3] relative to [1] as the origin. Considering the potential [2]—[1], how may this be obtained from the diagram ? For clearness let us examine a specific example say for a frequency of 500 cycles. The potential required is made up of

[2]—[3]. + [3]—[1]. Now [2]—[3] is OA′ and as [1]—[3] is A′C ([2]—[3] + [1]—[3] equalling the applied potential [0]—[3]) it will be seen that [3]—[1] is a line equal in length to A′C but in the opposite direction, or AI, where I is a point on the biggest circle. The potential [2]—[1] is therefore expressed by the vector OI. Similarly for the same frequency the potential [1]—[2] = [1]—[3] + [3]—[2] is expressed by OE′ + E′I′ = OI′, which is equal and opposite to OI as it should be. Again it will be found that the other circles represent the locus of points tapped along the resistances, e.g., for a frequency of 2,500 cycles and when the slider S is

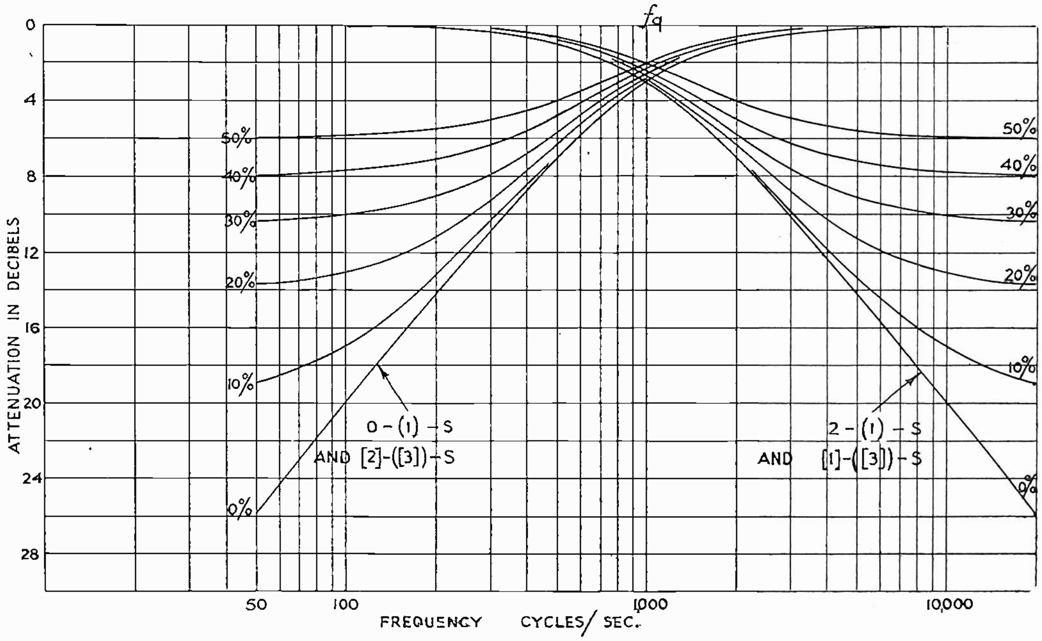


FIG. 4.

20 per cent. up the resistance [3]—[2] the point S would be represented on the diagram by J, which is the point at which the outer 20 per cent. circle cuts the 2,500 line, and the potential [1]—S by the line OJ. It is clear that the vectors [1]—[2] and [2]—[1] swing completely through 180°, as the frequency changes from zero to infinity, without changing in amplitude. The locus of [1] with respect to [2] as origin is the top semi-circle, and that of [2] with respect to [1] as origin the bottom semi-circle, and in both cases and as before the locus point moves anti-clockwise for increasing frequency.

It is clear that the construction shown in Fig. 3 provides a ready graphical means of calculating at any frequency the relative potential between any two points in Figs. 1A and 1B. The curves shown in Figs. 4 to 9, which show the relative amplitude to the applied potential in decibels and also the phase angle in degrees

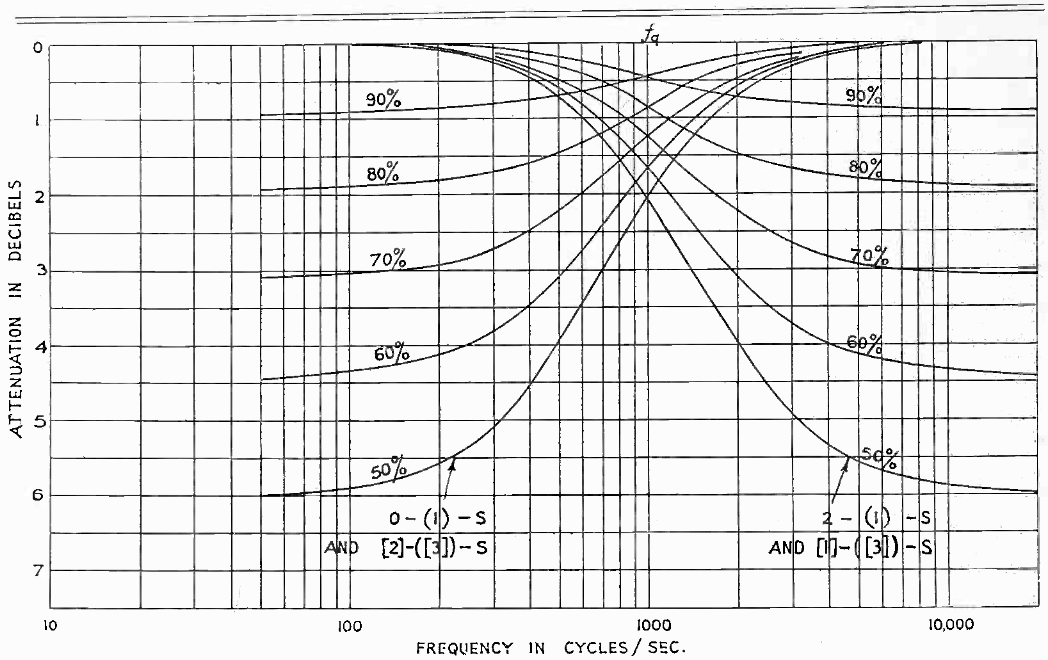


FIG. 5.

for the various tapping positions both for the cases 0—(1)—S, 2—(1)—S of 1A, and [2]—([3])—S and [1]—([3])—S of 1B. The basic curves so obtained can be applied

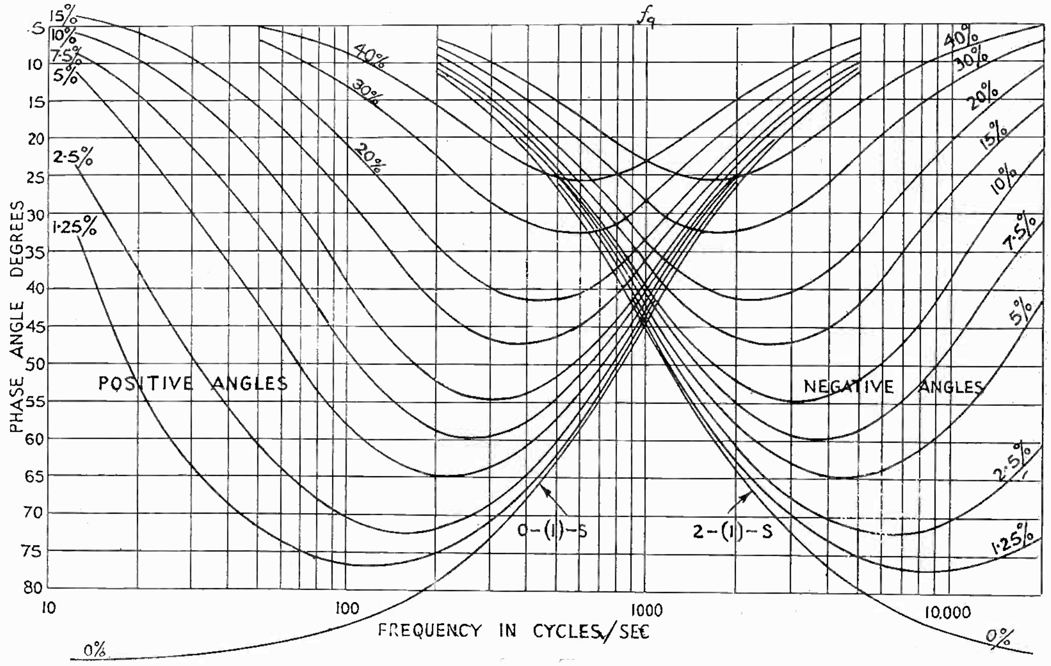


FIG. 6.

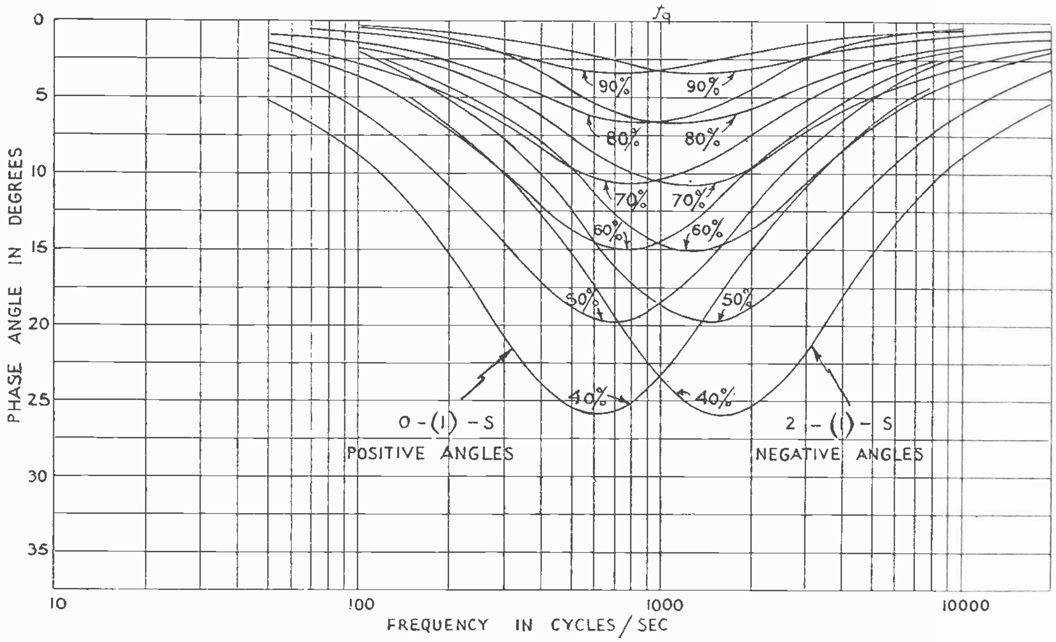


FIG. 7.

not only for cases worked out, where the quadrantal frequency has been assumed to be 1,000 cycles, but as will be shown below they are readily adaptable to other

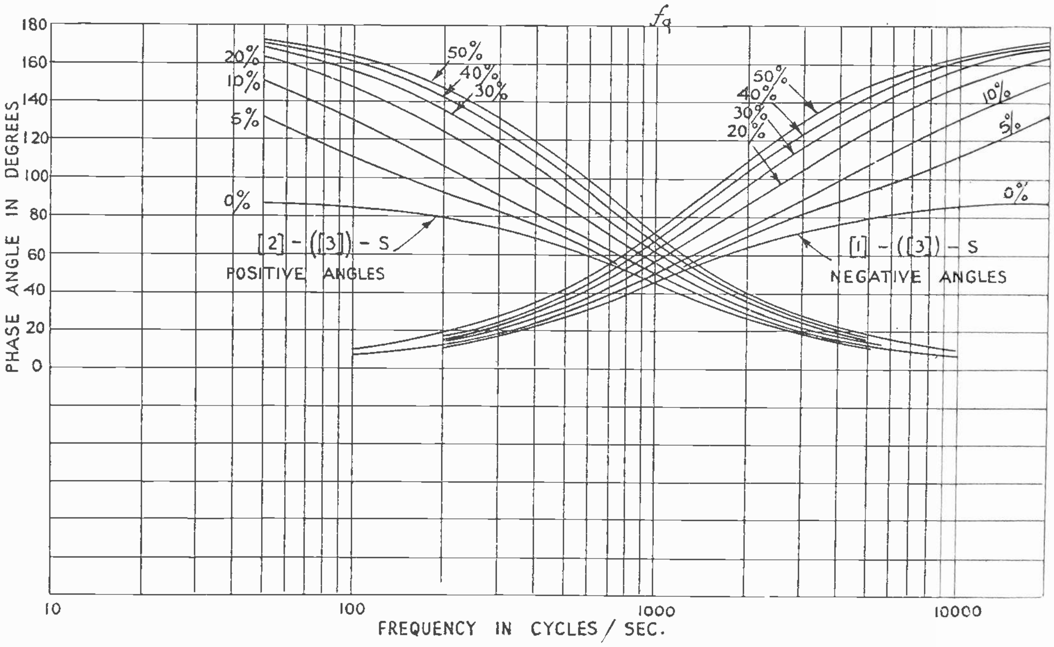


FIG. 8.

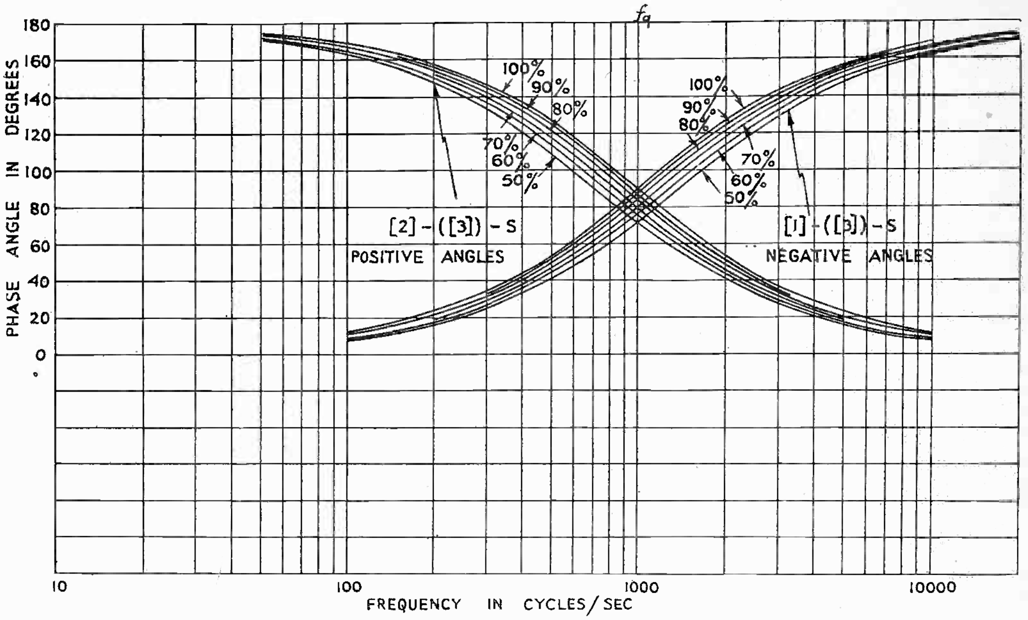


FIG. 9.

quadrantal frequencies. Also it is possible by circuit combinations to multiply the attenuation effects, and by the use of resonant arms correctly designed to make the attenuation effects take place over a relatively narrow frequency spectrum, but before considering the more complex types of circuit it will be well to examine the basic circuits already considered in relation to the group of curves.

Considering 1A, if a variable frequency of constant E.M.F. were applied at terminals 0 and 2 and readings were taken of the voltage 0—(1)—S (where the symbol 0—(1)—S is employed to indicate that the point 1 is between 0 and S) through the frequency range for various positions of the slider S and a series of curves plotted in which these results were shown, the curves in Figs. 4 and 5 would be produced, allowing for some deviation from the theoretical curves due to the resistance of the inductance and condenser and in some cases due to the fact that the voltmeter used to read the output voltages might not be of negligible resistance in comparison with the resistance R. As the slider is moved along from 0 per cent. to 100 per cent., the locus point which defines the potential of S sweeps out smaller and smaller circles until when it reaches 100 per cent. it is stationary at C indicating that the voltage is just that of the applied voltage at all frequencies. Thus as the tapping point moves up the attenuation range is decreased, while it will be found that at 0 per cent. in the theoretical case infinite attenuation is reached at zero frequency, whilst when the slider is moved to 20 per cent., for example, the amplitude at the lowest frequencies does not fall below 20 per cent. of the applied E.M.F. Another effect which is also clearly illustrated by the curves and may be graphically interpreted from the diagram is that at the higher tappings the curves more rapidly approach their assymptotic values as the frequency is decreased. If the curves are plotted on a logarithmic frequency scale, as is shown, an exactly symmetrical set of curves, relative to the quadrantal frequency axis, are obtained for the case showing the voltage 2—(1)—S, but with attenuation increasing as the frequency is raised.

Similarly for Figs. 6 and 7, the phase angle curves are symmetrical to each other as the frequency scale is logarithmic, but the scale for one group of curves must be interpreted to read positive angles, and the other negative angles. It will be noticed that the phase change never exceeds 90° and that for each tapping a maximum phase angle is reached. The frequency at which this maximum occurs swings across the higher attenuation range of the curves as the tapping percentage is increased and at high percentages tends to the quadrantal frequency. An inspection of Fig. 3 shows that this is clearly to be expected.

The same set of curves show the attenuations in the cases corresponding to 1B; the curves attenuating at the lower frequencies referring to case [2]—([3])—S and the other set to [1]—([3])—S. On the other hand the phase angle curves are completely different as the phase alteration through the frequency range is 180°. In general in the practical application of the circuits the basic circuits corresponding to 1A are used where amplitude correction is desired, and those of 1B are used where phase or combinations of phase and amplitude correction are desired.

Although the curves have been drawn out for the case of a quadrantal frequency of 1,000 cycles, they are readily adaptable for other quadrantal frequencies, as they are drawn to a logarithmic frequency base and hence their shape does not alter as the frequency range is changed. An illustration of how they are applied in a specific case will make this clear. Suppose a circuit required correcting in a definite frequency band and it was found that the simplest form of circuit would meet the requirements. Its attenuation curve would be plotted out to the same scale, both in attenuation, and in the logarithmic frequency scale, as the group of curves to be used for correction, but with attenuation in decibels, plotted upwards. The curve would then be traced on transparent paper marking the axes and a few frequency lines and the curve superimposed on the group of curves and slid over them until a curve of the same shape over the range of correction required was found (taking care to keep the ordinate axes parallel all the time). The quadrantal frequency line from the group of curves beneath would then be traced through and by replacing the traced curve over the original the quadrantal frequency corresponding to these conditions would be read off on the frequency scale beneath. More complicated cases are worked out on the same general principles.

(To be continued.)

N. M. RUST.

TRANSATLANTIC WIRELESS ANNIVERSARY

INTERNATIONAL "ROLL CALL" TO CELEBRATE FIRST LONG DISTANCE WIRELESS SIGNAL OF THIRTY YEARS AGO

TRIBUTES TO MARCHESE MARCONI

SATURDAY, December 12th, was the thirtieth anniversary of the historic wireless experiment conducted by Marchese Marconi between the Poldhu wireless station, in Cornwall, and St. John's, Newfoundland, which resulted in the transmission and reception of the first wireless signal across the Atlantic.

The long distance wireless communication thus inaugurated by Marchese Marconi has grown, in the intervening thirty years, to a world-wide system of wireless stations covering every country of importance in the world. The original scope of wireless has also been very considerably extended. One of the first of its principal uses was in organising communication between ships at sea and the shore, and it is hardly necessary to refer to the inestimable advantages which shipping and all connected with it has enjoyed from the adoption of this system of communication. Safety at sea has been enormously increased and navigation has been aided in many ways by its use. For business and pleasure wireless has now become an integral part of a ship's equipment, and to-day there are few ships which have not a means of immediate and continuous communication with land.

Three thousand British ships carry Marconi wireless apparatus to-day, and many thousands more carry wireless apparatus supplied by other national companies which owe their existence to his genius. The number of lives and the amount of property saved by Marchese Marconi's invention is incalculable. Aerial navigation too, analogous as it is to ocean travel, has benefited from wireless communication which is now an essential part of the organisation of commercial air routes.

In scientific work, surveying, exploration, in fighting forest fires, in linking up lightships and lighthouses with harbour authority headquarters, in providing communication by telephony and telegraphy for isolated settlers, for naval and military purposes, and for bringing amusement into the homes of every member of the community, wireless has shown itself to be of almost unbounded application and usefulness. For all this, while not forgetting that many other inventors have made valuable contributions to the science and art of wireless, congratulations are due to Marchese Marconi, the pioneer of commercial wireless communication, on the celebration of this thirtieth anniversary.

Mr. David Sarnoff's Tribute to Marconi.

The occasion was celebrated by a wireless roll call of sixteen nations, organised by the National Broadcasting Company of America on December 12th which was described in the American newspapers as "Marconi Day."

This roll call of the world began in Washington, where Mr. Merlin H. Aylesworth, President of the National Broadcasting Company, introduced Mr. David Sarnoff, President of the Radio Corporation of America, who recalled how a doubting world at the opening of the twentieth century had regarded wireless telegraphy as a dreamer's fancy. He described Marconi as a world benefactor and congratulated him on always continuing in the forefront of the research which followed his first amazing work. "Always imaginative but never visionary, never resorting to bombast or vain prediction, always searching for the practical, he had carried the art of wireless through succeeding steps until at last he had dispatched his signals beyond the wide expanse of the ocean," said Mr. Sarnoff.

"In the history of invention one finds no forward stride more truly the result of one man's inspiration and industry. Countless millions had lived before Marconi. About them through the ages slumbered the force of radio. Destiny had selected this youth of twenty-two summers as its agency for shaking this phenomenon from the wonder-box of nature. It might almost be said that, in winning a new dominion, Marconi wiped out the last frontier that baffled man's penetration and enslaved the infinite mysteries of space itself.

"The manner in which we are paying this tribute is an evidence of the magnificence of Marconi's gifts. A great invention is a key unlocking the door to a new era. One never knows what lies beyond. In his laboratory at Bologna the youth who was rendering serviceable the Hertzian waves could never have envisioned this world-wide broadcast. Yet, step by step the services and facilities have been created that have made it possible. Enterprise, inventive

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W.H. Corby, R.N. Vyvyan, A.J. Clark, F. Archer, J. Harvie Clark,

Sir Ambrose Fleming, A.H. Atkinson, E.E. Triggs,

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W.S. Entwistle, W.J. Willey, G.H. Green, A. Eve, Capt. C.V. Daly, G. Pells, E.G. Tyler,

F.E.D. Pereira, F.K. May, A.H. Ginman, A. Vanderpooten, R. Poupart, H.E. Dunn, F. Huff,

1902.

E. Berry, W.F. Thomas, R.D. Bangay, F.E. Burrowes, W. Davies, Capt. H.J. Round,

H.A. Ewen, E.C. Richardson, A.A. Kift, J. Lewis, H.E. Watterson, R.G. Newman,

1903.

D.W. Tulloch, J.R. Stapleton, F. Jones, J. Harvey, A.J. Huff, H.T. Worrall, E.T. Hills, L. Verbrugghen

1904

H.J. Tattersall, A.J. Irvene, T. Iddon, W.A. Taylor, W.I. McGhee,

J.R. Robinson, W. Platt, W.J. Collop, W.N. Ball. F.S. Hayburn,

A. Cappelaere, W. Tasker, H. Cornwall. F. Delasse, W.J. Gray

1905

S.C. Parish, J.N. Johnson, W.B. Cole. E.J. Wagstaff. C.A. Manson,

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A.M. Young, D. Sutherland, S. Stansbridge, Seton Smith. A. Ashley, W. Rogers.

F. Baker, S.C. Hills, C.C. Howe, H.D. Humphries, R. Leith, J.C. Hawkhead.

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Roll of Marconi Veterans, 1931.

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The International Significance of Wireless.

"This broadcast to sixteen different nations is a demonstration, then, of the world's technical advancement as a heritage from Marconi's genius. It is likewise evidence of a greater contribution to world progress in which radio is but the instrumentality, the symbol. I refer to the increasing role radio is playing in the exchange of opinions between nations, in the universal understanding in such world tributes as this to-day to a world figure. Within the last fortnight we have heard the first debate between representatives of Oxford and Harvard Universities—dealing with a topic of vital public interest in Europe and America—transmitted on the radio trail blazed across the Atlantic by Marconi thirty years ago.

"Radio is the medium by which we may learn to appreciate the thoughts and aspirations of other peoples. What we have already had in international broadcasting is but an indication of how the force unloosed by Marconi may bring the people of the world into a new and closer relationship. Long years of effort and the expenditure of hundreds of millions of dollars in the interest of world amity could not so readily promote the cause of lasting peace as the work of this one inventor. Four hundred years earlier Marconi's compatriot Columbus annihilated an ocean barrier and found a new continent ; Marconi annihilated the barrier of space and discovered the neighbourhood of nations.

In the Vanguard of Radio Progress.

"I must say one other thing of Marconi. After the passing of three decades since he spanned the sea with wireless, he remains in the vanguard of radio progress, and to-day is giving to the world the results of his invaluable research in the field of ultra-short wave transmission. Being the true scientist, he has never been content with the immortality already won. On behalf of the industry with which I am associated and on behalf of the great number of workers who have struggled constantly to enlarge the scope and service of radio, I congratulate Senatore Marconi on the thirtieth anniversary of his great accomplishment. I have always been proud to call him my teacher and my friend."

The scene then shifted to London where Sir John Reith, Director-General of the British Broadcasting Corporation, introduced Marchese Marconi to his world-wide audience and said that in addition to the credit due to him for the commercial development of wireless which had effected a revolution in communications, he was to be honoured for the trait in him which impelled him ceaselessly to new experiments. There were not many, said Sir John Reith, to whom Gœthe's description of "exact fancifulness" could be more aptly applied than to Marconi. Nor were there many fields of human activity in which the happy combination of exactitude and imagination, such as was possessed by Marconi, were so essential.

Marchese Marconi's Speech.

Marchese Marconi then spoke from Savoy Hill, and, after thanking those who had introduced him for the kind sentiments they had expressed, compared his feelings that day with those thirty years ago when, instead of sitting in a comfortable room in London speaking words which he knew would be received and understood throughout the United States of America and beyond, he was standing in a bitterly cold room on the top of a hill in Newfoundland wondering if he would be able to hear the simple letter "S" transmitted from England.

Marchese Marconi then described the circumstances leading up to his decision to attempt to send a wireless signal across the Atlantic and detect it on the other side and the experiences of himself and his two assistants, Mr. G. S. Kemp and Mr. P. W. Paget, at St. John's, Newfoundland, on that historic occasion thirty years ago. He concluded by tapping out the letter "S" on a telegraph key as he had heard it first across the Atlantic in 1901.

The broadcasting pick-up was then switched to many cities in succession, speakers from the following countries paying tribute to Marconi's genius and achievement :—Belgium—Mr. Maurice Philippson, Director-General of the Institut National Belge de Radiodiffusion ; France—M. Guernier, Minister of Posts and Telegraphs ; Germany—Dr. Hans Bredow, Commissioner-General of German Radio ; Italy—Signor Carlo Formichi, Vice-President of the Royal Italian Academy ; Poland—Dr. Zygmunt de Chamiec, Director-General of Polskie Radio ; Brazil—Dr. Jose Amerigo de Almeida, Minister of Communications ; Japan—Dr. S. Inada, Director-General of Communications ; U.S.A.—Dr. Michael Pupin, Major-General Charles McK. Saltzman, Chairman of the Federal Radio Commission, and Mr. Fred Muller, President of the Veteran Wireless Operators' Association ; the Philippines—Mr. G. C. Butte, Acting-Governor ; Venezuela—General Martinez, Chief of Communications ; Argentina—Mr. Octavio S. Pico, Minister of the Interior ; Hawaii—Mr. Raymond C. Brown, Acting-Governor ; Canada—Mr. Alexander Johnston, Deputy-Minister of Marine.

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Dr. Michael Pupin said: "Marconi's letter 'S' was the shortest message ever broadcast across the Atlantic, yet no dispatch had ever carried more significance. No other message carried by the wings of the electric waves from the Continent of Europe to that of America had a deeper meaning. But Marconi alone understood its full import ; to him alone the message announced the early dawn of a new epoch of trans-oceanic communications. This awakened in his prophetic mind the vision which guided his great effort along the steep and arduous path which led to the great triumph of our radio art.

" Few of us understood the full meaning of Galileo's simple experiment of 300 years ago. when from the leaning tower of Pisa he dropped little weights and from their motion derived the laws which guide the motion of the planetary system. Few of us understand the full meaning of Marconi's vision which guided the growth of the wireless art from its humble beginning of thirty years ago to its great achievement of the present day. But just as all of us know and admire the sublime courage with which Galileo defended his new science, so all of us know and admire the sublime courage which enabled Marconi to transform his vision of thirty years ago into the beautiful reality of our present radio art.

" Italy can justly be proud of her two great sons, Galileo and Marconi, not only on account of the genius which created the prophetic visions, but also on account of the sublime courage which defended these visions until they became beautiful realities."

Veteran Wireless Operators Present Medal.

The Veteran Wireless Operators' Association of the U.S.A., through its President, Mr. Fred Muller, who spoke at the National Broadcasting Company's studio in New York, presented to Marchese Marconi a gold medal which was accepted on behalf of the inventor by Signor Emanuele Grazzi, Italian Consul-General at New York, and the radio roll call concluded by the relay of the letter " S " round the world from New York to the Philippines, Java, Europe and back to New York.

Marchese Marconi was inundated with telegrams of congratulation on the anniversary from all parts of the world. These telegrams included those from the Italian Foreign Minister, the Italian Senate, the Italian Royal Academy and the Italian National Council of Research.

MARCONI VETERANS' DINNER

The fourth Annual Reunion and Dinner of the Marconi Veterans, comprising members of the staff who had completed 25 years service or more with the Marconi Company, or any of its associated companies, took place at the Holborn Restaurant, Kingsway, London, on Friday evening, November 27th, 1931.

There was a large gathering under the Chairmanship of Mr. C. E. Rickard, O.B.E., and the function was a great success.

Marchese Marconi, who at an earlier date had intimated his intention of attending, was unfortunately prevented by urgent business in Italy from arriving in England in time for the function.

Among those present were Col. Jameson Davis, Mr. H. W. Allen, Mr. Andrew Gray, Mr. C. S. Franklin, Mr. A. H. Ginman, Mr. H. J. Round, Mr. F. S. Hayburn, and others whose names have been well known in wireless for many years.

Telegrams of greetings and good wishes were received from Marchese Marconi, Marchese Solari, Capt. C. V. Daly, Mr. J. Lewis, and three veterans, Messrs. Gray, Dunn and Newman, in Canada, who were meeting at a similar function held by the Canadian Marconi Executives on the same evening in Montreal. Letters were also received from Monsieur M. Travailleur, of Brussels, and many others.

The gathering stood for a moment as a token of respect to the memory of two of their members, Messrs. F. J. Leathers and P. L. Rowland, whose deaths occurred during the year.

After the toast of the King, the Chairman in a short speech proposed the toast of His Excellency Marchese Marconi, from whom, he said, he had received a telegram of greeting, and regret at his unavoidable absence, and to whom he proposed to convey the greetings and best wishes of the Veterans, " that he may long continue to enjoy health, success and happiness." With this toast he coupled the names of " Col. Jameson Davis, our first Managing Director, Marchese Solari, the head of our agency in Italy, and Capt. Daly, our old and esteemed maritime collaborator."

The toast of the new members was proposed by Mr. F. S. Hayburn and replied to by Mr. J. C. Hawkhead. Mr. H. W. Allen proposed the Chairman, to which the Chairman replied.

An excellent musical programme was rendered throughout the proceedings.

All arrangements were as usual carried through by a Committee of Guarantors, for whom Mr. H. M. Dowsett acted as executive and Hon. Secretary, and Mr. Collop as Hon. Treasurer.