

Jan. 16, 1940.

E. C. CORK ET AL
DIRECTIONAL AERIAL SYSTEM

2,187,015

Filed June 18, 1938

4 Sheets-Sheet 1

Fig. 1

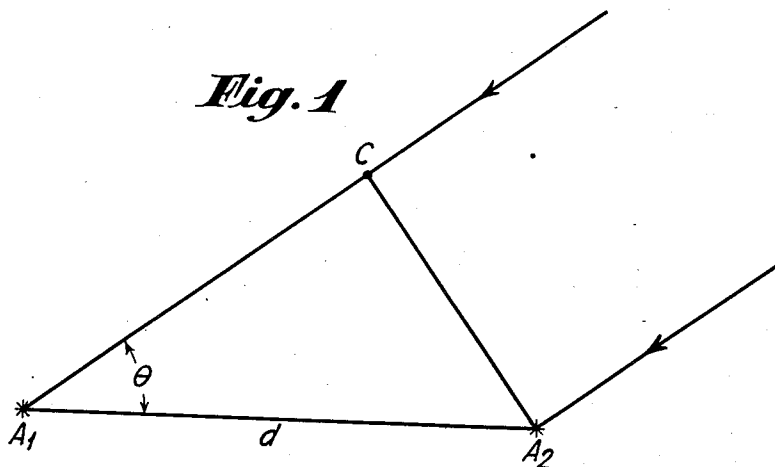


Fig. 2

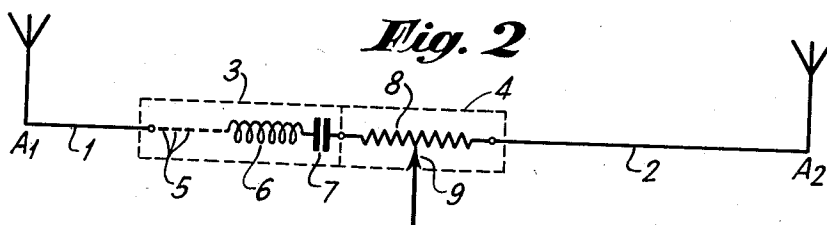
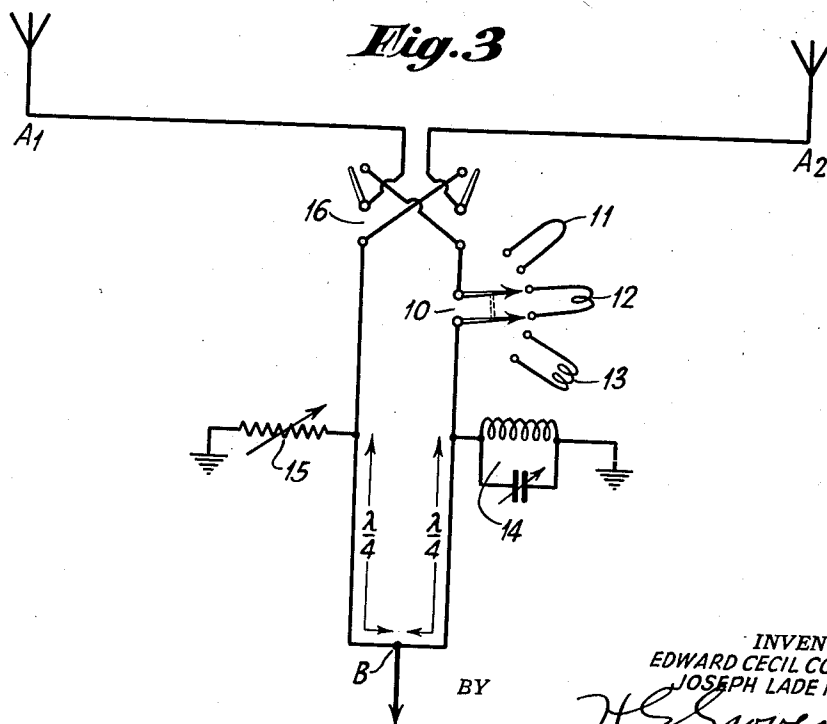


Fig. 3



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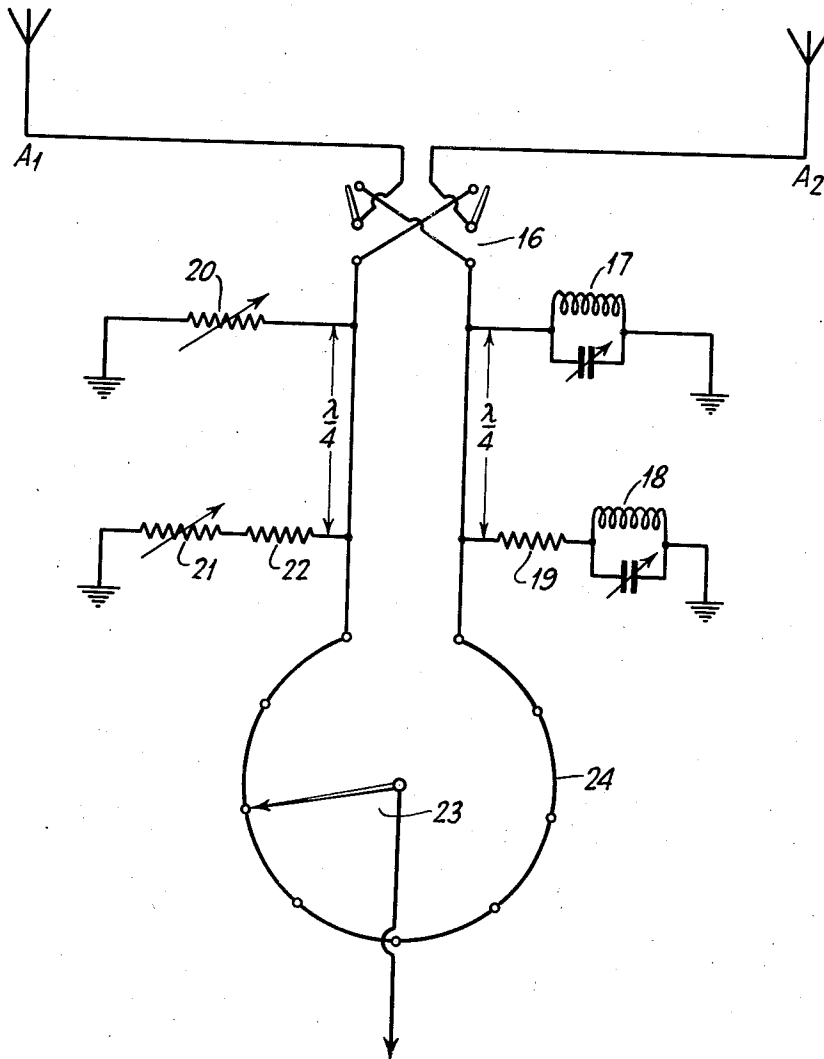
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Fig. 4



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Fig. 5

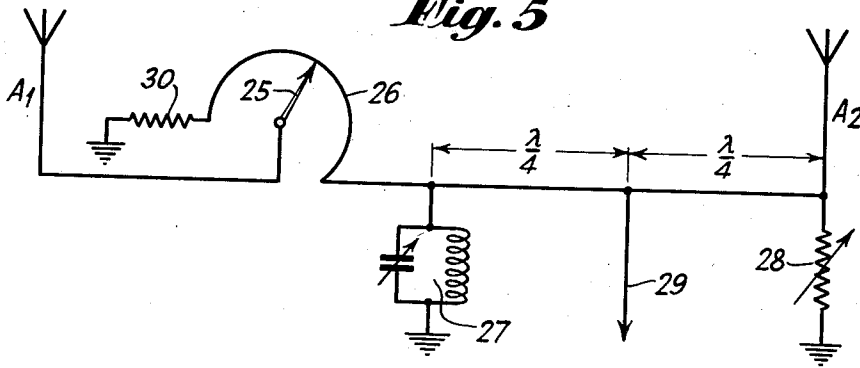


Fig. 6

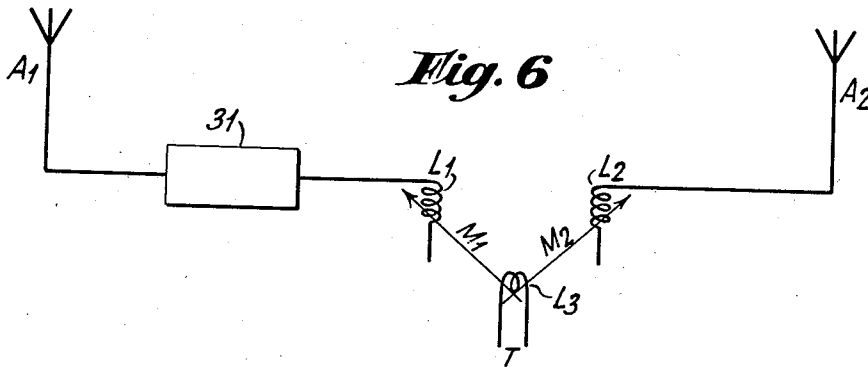
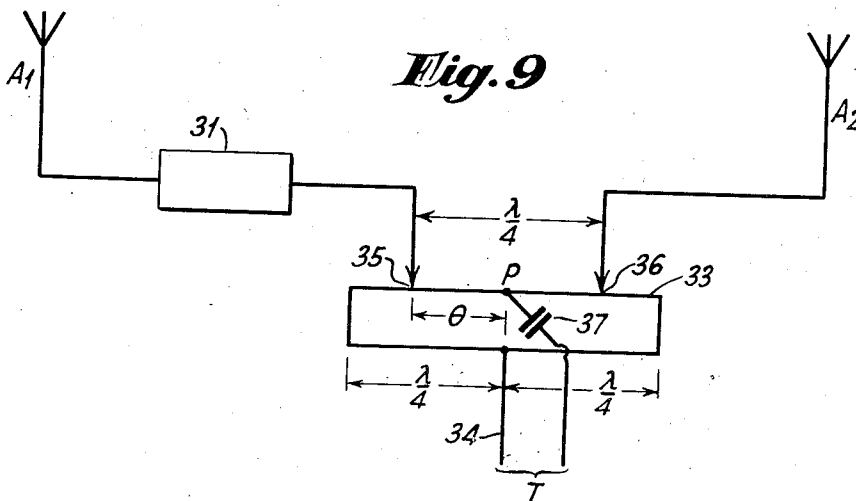


Fig. 9



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4 Sheets-Sheet 4

Fig. 7

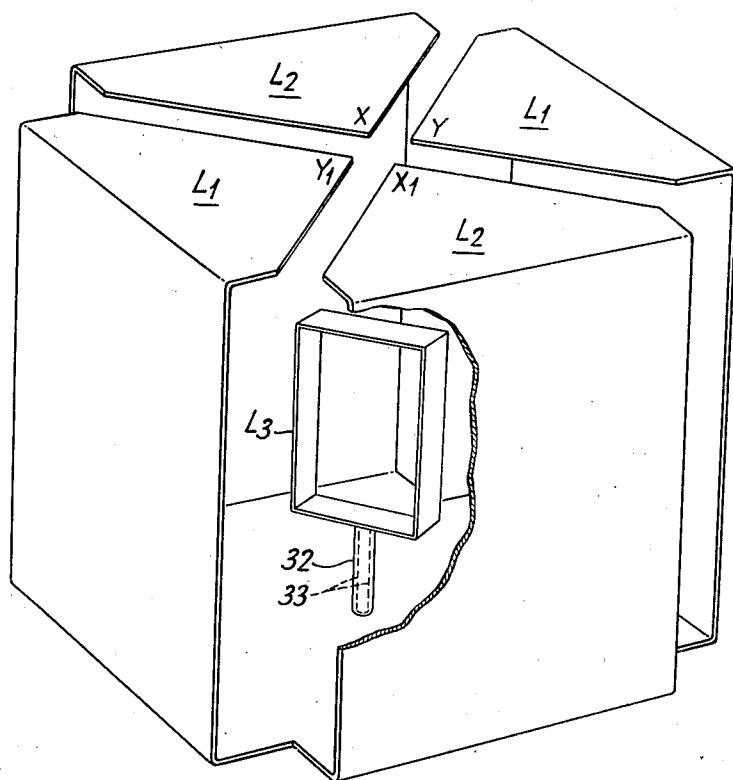
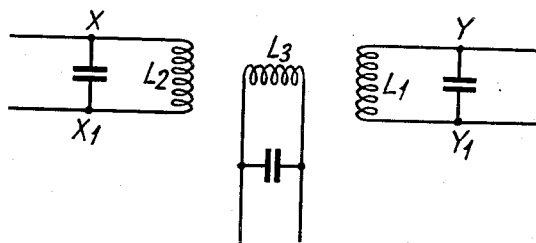


Fig. 8



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UNITED STATES PATENT OFFICE

2,187,015

DIRECTIONAL AERIAL SYSTEM

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In Great Britain June 26, 1937

3 Claims. (Cl. 250-11)

This invention relates to directional transmitting or receiving aerial systems, the directional properties being used in the case of transmitters to radiate signals in a predetermined direction and in the case of receivers, for the purpose of improving the signal to noise ratio, by increasing the pick-up signal and reducing the unwanted interference.

In a television receiving system for example, it may happen that intense interference may be set up by apparatus such as that employed for diathermy purposes. Providing that the angle between the wanted and unwanted signals is greater than a few degrees, it is possible to suppress the interference while retaining the wanted signal. In such cases it is highly desirable that it should be possible to arrange that the region of minimum pick-up in the directional diagram of an aerial array is in such a direction that there is a minimum of reception, and preferably a total suppression, of the unwanted signal and a maximum of reception of the wanted signal.

One object of the present invention is to provide electrical means which may be arranged so that the region of minimum pick-up in the directional diagram of a directional receiving aerial system is directed to the source of interference. In another set of circumstances it may be found that on the re-erection of an aerial array at another site, the situation of the region of minimum pick-up in the directional diagram which has been found satisfactory under ideal conditions for the suppression of interference is poor and displaced due to the presence of local objects causing a distortion of the field.

A further object of the invention, therefore, is to provide for selecting and improving the minimum pick-up region by electrical means to correct for local irregularities. It is a desirable feature that in combination with means of observation such as for example, a television receiver, the adjustment of the minimum referred to should be capable of variation in proximity to the receiver, so the reduction of interference may be observed and the interference eliminated as it arises.

Another object of the invention is to provide a directional transmitting system in which the region of maximum radiation in the directional diagram is in the direction in which it is desired to transmit signals.

According to the present invention a directional aerial system includes two aerals the energy in which is passed through an amplitude control arrangement to or from a common channel, phase adjustment being effected in one of the aerial leads in order to control the phase of signals passed to or from that aerial relatively to those passed to or from the other aerial to the common

channel. The phase adjustment may, for example, be effected by inserting selected lengths of conductor in the lead from the aerial to the amplitude controlling arrangement associated with that aerial, and provision may be made for continuously effecting fine adjustment of the phase displacement. Amplitude control may be effected by means of a variable resistance or by variable coupling transformer arrangements connected between the two aerals and the common channel.

In order that the invention may be more clearly understood and readily carried into effect, a directional aerial system embodying the invention will now be described by way of example with reference to the accompanying drawings in which:

Figures 1 and 2 are explanatory diagrams and Figure 3 shows diagrammatically one form of aerial system embodying the invention;

Figure 4 shows a modified arrangement of Figure 3. Figures 5, 6 and 9 show further modifications of the present invention, while Figure 7 shows a type of goniometer which may be used with the present invention and which is particularly adaptable to ultra short waves, and Figure 8 shows the electrical equipment of the goniometer shown in Figure 7.

Referring to Figure 1 of the drawings, two receiving aerals A_1 and A_2 are shown spaced apart at a distance d , and it is assumed that a signal is arriving at an angle θ to the line between the aerals. There is a phase difference between the signals induced in the aerals due to the path difference A_1C equal to

$$\frac{2d \cos \theta}{\lambda}$$

radians. If it is assumed that there is a further phase difference due to the aerial feeders and the phase adjusting arrangements at one or the other of the aerals, the phase difference being indicated by ϕ and the amplitudes are adjusted to equality, it can be shown that the picked up signal has an amplitude of

$$E = 2 \cos \left(\frac{d \cos \theta}{\lambda} + \frac{\phi}{2} \right)$$

which has a maximum value at

$$\frac{\pi d \cos \theta_{max}}{\lambda} + \frac{\phi}{2} = 0, \pi, \dots, n\pi$$

and a minimum value at

$$\frac{\pi d \cos \theta_{min}}{\lambda} + \frac{\phi}{2} = \frac{\pi}{2}, \frac{3\pi}{2}, \dots, \left(\frac{n+1}{2} \right) \pi$$

Hence

$$\cos \theta_{min} - \cos \theta_{max} = \frac{\lambda}{2d} \quad (1)$$

It will therefore be seen that if the spacing between the aerials is great

$$\left(\frac{\lambda}{d} \text{ small}\right)$$

the angle between the maximum and minimum of a loop is small, which indicates a large number of narrow loops.

If, therefore, the interference and signal differ in angle by a small amount, it is desirable to space the aerials apart by a considerable distance. It is preferred to make use of a suitable condition such that the interference falls on a region of zero pick-up in the directional diagram of the aerial, while the signal falls within the adjacent region of maximum pick-up.

For example, if the signal and interference differ in direction of arrival of 10 degrees and the direction of the signal is perpendicular to the line of the aerials (i. e. $\cos \theta_{\max} = 0$) then the spacing to give this condition would be

$$\frac{\lambda}{2d} = .174$$

$$\frac{d}{\lambda} = 2.88$$

However, it will be seen that the application of the invention is not limited to this condition, so that the aerials may be set up without exact knowledge of the direction of arrival. If the direction of arrival of the interference increases to 180°, the spacing given by the equation (1) decreases to

$$\frac{\lambda}{4}$$

In order that the nature of the phase and amplitude control arrangements may be more fully understood, reference will now be made to Figure 2 of the accompanying drawings which shows two aerials A_1 and A_2 and feeder lines 1 and 2 which are approximately matched to the aerials. The dotted rectangles 3 and 4 contain phase controlling and amplitude controlling arrangements respectively. The phase controlling network includes sections of feeder 5 which may be selectively included in or disconnected from the line by plug-in contacts or by a switching device. The selection of the lengths of feeder included enables phase adjustment to be effected in steps of 60° between 0 and 360° and finer adjustment of phase difference between the signals received may be effected by the provision of a tuned circuit including inductance 6 and capacity 7, which introduces a variable phase difference controllable by the condenser 7 of approximately plus or minus 45°.

The amplitude control device consists of a resistance 8 connected at opposite ends to the aerials A_1 and A_2 , and provided with a tapping 9 connected to a receiver not shown in the drawings.

A practical form of directional aerial system is shown in Figure 3 which includes two aerials A_1 and A_2 and a dial switch 10, which serves to connect selected lengths of line 11, 12 or 13 for coarse variation of the phase shift desired.

A parallel tuned circuit 14 is arranged at a point A a quarter of a wavelength away from the point B at which the receiver is connected, the tuned circuit serving to effect fine adjustment of the degree of phase shift. It is known that a parallel tuned circuit 14 connected as shown is equivalent to a series tuned circuit arranged at the point B and has the advantage of allowing one

side of the variable condenser forming part of the tuned circuit to be connected to earth.

A variable resistance 15 is connected at a point also a quarter of a wavelength away from the point B for the purpose of controlling the amplitude of the signals fed from one of the aerials to the receiver. In this case also the parallel connected resistance is equivalent to a resistance connected in series at the point B, but again the parallel connection enables one side of the resistance to be connected to earth. A changeover switch 16 enables the resistance 15 to be transferred to the aerial which has induced in it the greater undesired signal.

If it is more convenient the phase and amplitude control arrangements may be divided into sections on either side of the point B at which the receiver is connected, but the arrangement illustrated in Figure 3 of the drawings possesses the merit that the relative phase and amplitude controls are independent.

In the modified form of Figure 3 shown in Figure 4 the tuned circuit 14 of Figure 3 has been replaced by two identical tuned circuits 17 and 18 and a resistance 19 equal in magnitude to the characteristic impedance of the feeder (Z_0) has been added in series with the tuned circuit 18. The variable condensers of the tuned circuits 17 and 18 are ganged together for simultaneous adjustment.

In a similar manner the resistance 15 of Figure 3 has been replaced in Figure 4 by two equal variable resistances 20 and 21 connected to points in the feeder a quarter of a wavelength apart. The resistances 20 and 21 are also ganged for simultaneous adjustment. A resistance 22 is connected in series with the variable resistance 21 and has a value equal to the characteristic impedance of the feeder (Z_0).

It is a property of the network including the resistances 20, 21 and 22 that when matched at the aerial end, the input impedance at the point of connection of the resistance 22 to the feeder, is equal to the value of the characteristic impedance of the feeder independently of the value of the resistances 20 and 21.

Variation of the resistances 20 and 21 serves to vary the attenuation of the signals from the aerial to which they are connected without change of phase. Similarly, the network including the tuned circuits 17 and 18 and the resistance 19 has a constant input impedance at the point at which the resistance 19 is connected to the feeder and variation of the ganged condensers of the tuned circuits from the tuned position varies the phase of the signals received from the aerial to which they are connected substantially without attenuation. Coarse phase adjustment is provided by a rotary switch 23 which serves to select tapping points along a conductor 24 which is one half a wavelength long.

Referring, now, to Figure 5 of the accompanying drawings, a modification is shown in which coarse phase adjustment is effected by connecting aerial A_1 through a switch 25 to a variable tapping point in a length of feeder 26 which may be about one wavelength long. Fine phase adjustment is effected by the tuned circuit 27, amplitude control being effected by the variable resistance 28. The lead 29 is connected to a receiver as in the preceding arrangements. The length of feeder 26 is terminated by a resistance 30 approximately equal in value to the characteristic impedance of the length of feeder 26. The resistance 30 allows a very simple tapping switch

25 to be used without variations due to the varying length of the dead end of the length of feeder 25.

While the invention has been described with reference to Figures 2, 3, 4 and 5, particularly in connection with receiving aeri-
als, it will be understood that it is equally applicable to transmitting aeri-
als. In both the cases of transmitting and receiving systems, it is of course desirable to avoid waste of power as much as possible, and as the amplitude control by means of variable resistance does involve waste of power, the following methods of effecting amplitude control offers alternatives which may be adopted and are of particular advantage in the case of transmitting systems.

Thus referring to Figure 6 of the drawings an arrangement for effecting amplitude control by means of variable mutual inductances M_1 and M_2 is shown, phase control being effected as shown in Figure 2, for example, the rectangle 31 representing the phase controlling device. The aeri-
als A_1 and A_2 are connected to coils L_1 and L_2 respectively, a coil L_3 coupled to the coils L_1 and L_2 , having tappings brought out to a switch (not shown) and being connected to a transmitter or a receiver by the leads T . As the ratio

$$\frac{M_1}{M_2}$$

is varied by switching in more or less turns of the coil L_3 the relative amplitudes in the aeri-
als is affected. It is desirable that L_1 and L_2 should not have direct coupling with each other and that as the coupling M_1 and M_2 varies, the load on the transmitter should remain constant.

This latter condition requires for similar aeri-
als that

$$\frac{\omega^2 M_1^2}{r_1} + \frac{\omega^2 M_2^2}{r_2} = \text{a constant.}$$

Both of these conditions are satisfied if the coils L_1 and L_2 are arranged at right angles to each other and the coil L_3 is angularly disposed with respect to them in a manner of a radio goniometer.

The coils L_1 , L_2 and L_3 may take the form shown in Figure 7, the electrically equivalent arrangement being shown in Figure 8. The coils L_1 and L_2 are made from a piece of copper sheet, cruciform in shape, the limbs of the cross being bent up to form a box like structure as shown. The coil L_3 is formed of strip copper narrower than the strips forming the coils L_1 and L_2 and is mounted on a hollow shaft 32 so as to be rotatable within the box formed by the strip coils L_1 and L_2 . The leads 33 to the coil L_3 pass through the hollow shaft 32. The relation between the physical form of the coils and the electrical circuit as shown in Figure 8 the points $X-X_1$ and $Y-Y_1$ having corresponding positions in the two figures.

The values of L_1 , L_2 , M_1 , M_2 may be selected to give a unity transformation ratio so that the same feeder may be used throughout and the feeder to the transmitter or receiver remaining matched for any setting of the coil L_3 . Alternatively other transformation ratios may be obtained by adjustment of the coil dimensions. Each coil is individually tuned and the appropriate feeder connected in parallel across the tuned circuit formed.

The arrangement described with reference to Figures 7 and 8 is adapted to use balanced feeders but it is probable that in view of the very low impedance circuits obtained with this construc-

tion, concentric feeders may be used without impairing the effectiveness of the device.

An alternative method of effecting amplitude control is shown in Figure 9, in which the coupling arrangement shown in Figures 7 and 8 is replaced by a tapped half wavelength line. The aeri-
als A_1 and A_2 are connected to points on a half wavelength line 33 short circuited at each end and connected at its center to a transmitter or receiver by a lead 34. The tapping points 35 and 36 are maintained at one quarter of a wavelength apart and the variation of amplitude is obtained by moving the tapping points simultaneously along the line 33. The input impedance at the mid point P of the line is

$$Z = R + jZ_0 \sin \theta \cos \theta$$

where R is the resistance of each aerial assumed to be equal and Z_0 the characteristic impedance of the half wavelength line.

If the reactance is tuned out as indicated by the condenser 37 the device forms a unity ratio transformer. The relative amplitudes in the aeri-
als A_1 and A_2 is given by $\tan \theta$. For a small range of amplitude control the reactance will not materially change assuming Z_0 to be suitably selected so that the system remains substantially tuned.

The invention may be applied not only to dipoles and similar aeri-
als, but generally to directional systems. It could, for example, be used in a system combining different types of aeri-
als to produce several controllable regions of minimum pick-up or radiation in a directional diagram. In the case of reception, it will be seen that the arrangement described enables the direction of reception of the array to be changed by electrical means, and complete suppression of any given fixed source of interference may be effected even in the presence of distortion of the field caused by neighboring objects. It will be seen also that the interference suppressing arrangements are located at the receiver so that interference from a given source may be suppressed when it arises.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:

1. A directional aerial system including two aeri-
als, an aerial lead connected to each aerial, a common channel coupling said leads to a transducer, means connected to one of said leads for varying the phase of signals therein with respect to signals in the other lead and means in the other of said leads for varying the amplitude of signals therein with respect to the signals in said first lead, said first means comprising an inductance and a capacity connected in parallel and connected to a point in said aerial lead one quarter of a wavelength from the point of connection of said leads to said common channel and said second means comprising a variable resistance connected at a point one quarter of a wavelength from said point of connection of said lead to said common channel.

2. A directional aerial system including two aeri-
als, an aerial lead connected to each aerial, a common channel coupling said leads to a transducer, means connected to one of said leads for varying the phase of signals therein with respect to signals in the other lead and means in the other of said leads for varying the amplitude of signals therein with respect to the signals in said first lead, said first means comprising an

- inductance and a capacity connected in parallel and connected between a point in said first aerial lead one quarter of the wavelength from the point of connection from said leads to a common channel and ground, said second means comprising a variable resistance connected between a point one quarter of a wavelength from said point of connection in said other aerial lead and ground.
3. A directional aerial system including two aerial leads connected to each aerial, a common channel coupling said leads to a transducer, means connected to one of said leads for varying the phase of signals therein with respect to signals in the other lead, and means in the other of said leads for varying the amplitude of signals therein with respect to signals in said first lead, said first mentioned means comprising a pair of identical parallel tuned circuits spaced apart by one quarter of the length of the operating wave and connected between ground and said first aerial lead, a resistance equal in magnitude to the characteristic impedance of said lead being connected in series with one of said parallel tuned circuits, said second means comprising a pair of equal resistances spaced apart by one quarter of the length of the operating wave and connected between ground and said other aerial lead, a resistance equal in magnitude to the characteristic impedance of that lead being connected in series with one of said resistances whereby the phase of the signals in one of said leads may be varied without variation of the attenuation, and the attenuation of the signals in the other of said leads may be varied without change of phase in the signals in that lead.

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