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DIRECTIONAL ANTENNA

Filed Sept. 28, 1940

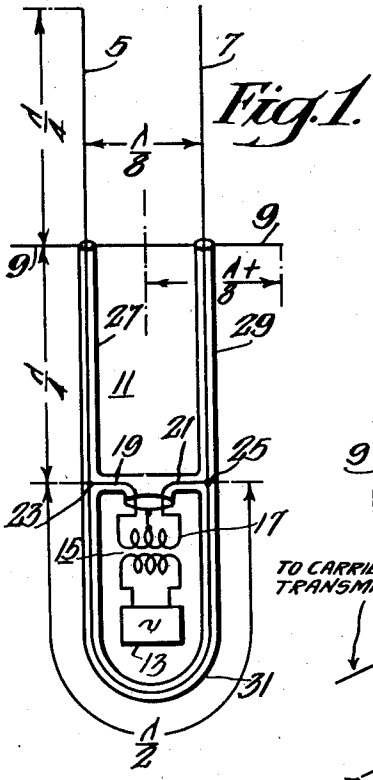


Fig. 1.

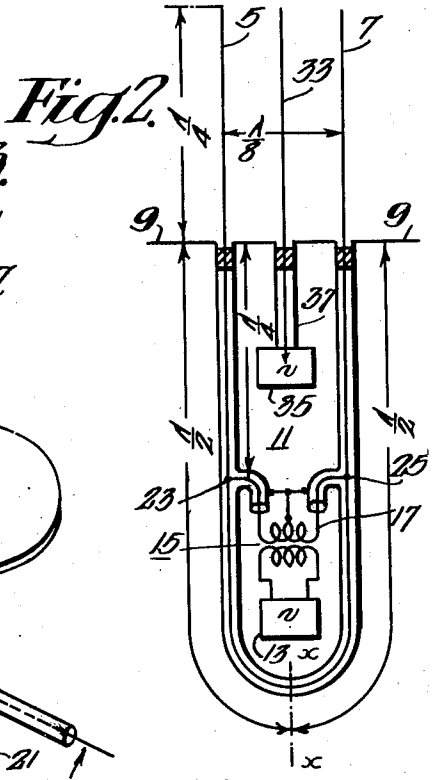


Fig. 2.

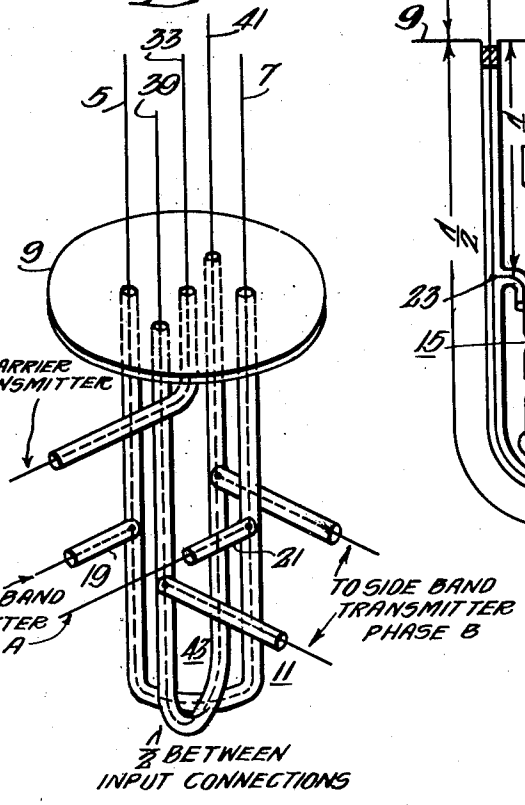


Fig. 3.

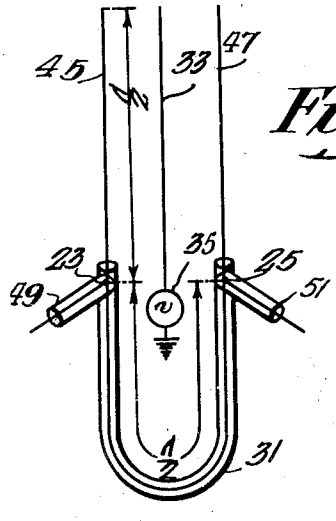


Fig. 4.

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DIRECTIONAL ANTENNA

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18 Claims. (Cl. 250—33)

This invention relates to high frequency directional antennas of the Adcock type which are utilized to produce radio beacons and the like.

As is well known, a fixed Adcock antenna comprises four antennas located at the corners of a square, diagonal pairs of antennas being energized in relative phase opposition. In addition, a fifth antenna is used in some installations, for supplying an omnidirectionally radiated field. In such case, the fifth antenna is mounted at the center of the square formed by the other antennas and may be energized by carrier currents, while the pairs of antennas comprising a directional array are energized by side band currents. It has been recognized that the two antennas of each directional pair must be energized by currents which are exactly in phase opposition and exactly equal in amplitude if the directional pattern is to have the desired characteristics. By employing carefully equalized circuits, no particular difficulty is experienced in low frequency antennas of this type, but the problem of maintaining the amplitudes and phases of the antenna currents in their desired relations increases as the operating frequency of the system is increased.

It is, therefore, the principal object of the present invention to provide a stabilizing system which is particularly applicable to high frequency Adcock antennas, and the like, for maintaining energizing currents in substantial phase opposition and equal amplitude. In brief, this object is accomplished in accordance with the present invention by suitably coupling a half wave resonator between each pair of antennas, so that the stabilizing characteristics of a resonant line are utilized to produce the desired result.

Radio range antenna systems of the type referred to above in which carrier frequency currents are applied to a centrally located antenna, as well as other antenna systems in which carrier and side band currents are applied separately to different antennas, have heretofore been subject to a disadvantage which it is the further object of this invention to overcome. It will be observed that the central or carrier antenna is closely coupled to the directional pairs of antennas and that all antennas are operated at substantially the same frequency. Consequently, strong currents are induced in each of the directional antennas from the carrier antenna. The reverse is not true, however, since, as noted above, the directional antennas are energized in phase opposition so that the carrier antenna, being symmetrically located with respect to the other antennas, is in a plurality of fields of instantaneously equal and opposite polarity, so that no resultant current is induced in the said carrier antenna. The currents induced in the directional antennas by the carrier or omni-directional antenna are in relative time phase. These currents frequently become very large and are very troublesome when measurements of current distribution in the directional antennas are attempted. These induced in-phase currents do not improve the desired radiation pattern and, consequently, are highly undesirable, since they represent loss, and may interfere with the adjustment and operation of the system.

It is a further object of this invention to minimize the cophased currents induced in the directional antennas by the omni-directional antenna without affecting the contraphased currents which are fed to the directional antennas from the transmitter. Other objects of this invention include the provision of an improved high frequency directional antenna system; and the provision of a unique structural design which provides phase stability and reduces the undesired coupling between elements of the antenna system.

In brief, the induced currents flowing in the directional antennas are minimized by connecting a resonant line between the bases of diagonally disposed antennas of each directional pair, and by applying input to this line at points removed from the bases of the antennas a distance which depends on the type of antenna. For a quarter wave vertical antenna this distance should be quarter-wave length. This invention will be better understood from the following description when considered in connection with the accompanying drawing in which Figure 1 is a schematic view of a simplified form of this invention; Figure 2 is a schematic view of a directional antenna having a pair of oppositely phased radiating elements and an omnidirectional antenna; Figure 3 is a perspective view of a directional antenna system embodying the improvements described in the present application; and Figure 4 is a schematic view of a half wave antenna system embodying this invention. Similar reference numerals refer to similar elements throughout the several figures of the drawing.

Figure 1 represents a directional antenna for producing a figure-of-eight radiation pattern. It comprises two spaced vertical quarter-wave antennas 5 and 7, insulated at their bases, and mounted at right angles to a conducting surface or counterpoise 9. A concentric transmission line

11 has its opposite ends connected to the bases of the two quarter wave vertical antennas 5 and 7. The outer conductors of the line are connected to the counterpoise, which may be ground, the inner conductor being connected to the antenna elements. A source of radio frequency energy 13 supplies approximately contraphased energizing currents for the antennas. Coupling is accomplished in any conventional manner as, for example, by means of a transformer 15 having a center-tapped secondary 17, the opposite terminals of which are connected through transmission lines 19 and 21 to the line 11 at points 23 and 25 which are a quarterwave from the junctions of the line and the antennas. While this line 11 has been shown as a concentric unitary line, it will be appreciated that it may be made up of sections of line of lesser length, or a conventional balanced line may be used.

It will be observed that, between the feed points 23 and 25 and the antennas 5 and 7, there are, respectively, two quarter-wave transmission lines 27 and 29, which are preferably designed to act as impedance-matching transformers between the bases of the antennas and the transmission lines 19 and 21 which are coupled to the transmitter. The close coupling between the oppositely phased antennas changes their base impedances from the usual base impedance of a single quarterwave antenna. It will be found that the base impedance of each antenna is approximately 5 ohms in the given case. If the transmission line from the antenna is a conventional 70 ohm line, the characteristic impedances of the quarter-wave sections 27 and 29 should be 19 ohms to match the 5 ohm base impedances of the antennas to the feeder line impedances.

Neglecting for the moment the central half-wave section 31 of the line 11, which may be considered as a separate line connected across the ends of the quarter-wave transformers remote from the antennas, it will be appreciated that the antenna functions in a normal manner, the two elements being coupled to the transmitter through conventional impedance-matching transformers. The function of the half-wave line 31 will now be considered.

It is a well-known characteristic of a half-wave resonant line that the voltage at one end is equal and in exact phase opposition to the voltage at the other end. Consequently, if such a line is connected across 2 points, the line tends to maintain the voltages at these two points in phase opposition at all times, notwithstanding small inequalities in the transformer 15, lines 19, 21 and the antennas. The stabilizing effect may be made quite strong by providing a half-wave line of low loss and by suitably matching its impedance to the impedance of the points in question. In accordance with the present invention, therefore, the half-wave line 31 is a low loss line whose characteristic impedance is equal to or less than that of the quarter-wave transformers. The half-wave line, by reason of its well-known stabilizing action, constrains the voltages at feed points 23 and 25 to exact phase opposition. Since the quarter-wave transformers are then fed with equal and opposite voltages, the antenna currents are necessarily equal and opposite in like manner, since quarter-wave lines, when properly adjusted, are stable impedance inverters. As a result, the currents in the two antennas 5 and 7 are maintained in their desired contra-phasal relation notwithstanding changes in the transmitter or in the transmission lines connecting the transmitter to the antenna system.

While the antennas 5 and 7 have been described as "quarter-wave antennas," it is to be understood that their lengths may be any odd number of quarter-wave length without affecting the function or utility of the stabilizing section. The half-wave stabilizing line can also be connected between the bases of a pair of antennas of lengths equal to an even number of quarter-wave lengths, as will be described hereinafter.

The stabilizing section 31 connected in the manner described also has a second important function. It functions to reduce the in-phase currents which may be induced from another antenna, as shown in the embodiment illustrated in Figure 2. The antenna arrangement illustrated in this figure is identical to that of Fig. 1 except for the addition of a third antenna 33 centrally located between the antennas 5 and 7 of the directional pair. This central antenna 33 is separately energized from a source of radio frequency current 35 through a transmission line 37 which may include an impedance-matching transformer, if required. As indicated above, no currents are induced in the central antenna 33 by the antennas 5 and 7 of the directional pair, by reason of symmetry, and the fact that the latter are energized in phase opposition. However, the central antenna is very closely coupled to the outer antennas and induces in each of them currents which have the same instantaneous phase. In the absence of the half-wave stabilizing line 31, large currents may flow from the antennas through the transmission lines to the transmitter and thence to ground. I have discovered that the addition of the stabilizing section 31 not only functions in the manner described above to maintain the desired currents in the antennas 5 and 7 of the directional pair in phase opposition, but also to minimize the in-phase currents induced in these antennas by the centrally located antenna.

Considering the line 11 as a pair of half-wave lines open at the ends remote from the antennas, it will be observed that the bases of the vertical antennas 5 and 7 are effectively open-circuited as to currents flowing in phase through the two lines. The reason for this is that, as is well known, a resonant half-wave line reproduces at one end the impedance impressed on the opposite end. Considering, therefore, that these lines are open-circuited at the axis X—X, points a half-wave length distant are likewise open-circuited, and, since the antennas are connected to the lines at such points, it may be said that the base of each antenna is open-circuited with respect to the counterpoise. A quarter-wave antenna is resonant only when considered in conjunction with a counterpoise, or ground, and consequently, if the base of the vertical antenna is open-circuited, it can no longer be resonant, and its pickup is, therefore, greatly reduced.

Since the above argument is based on an assumption that the full-wave line 11 is open-circuited at the axis X—X, and since it is apparent that these lines are not physically disconnected at this point, it is necessary to find a condition in which the two half-wave lines are effectively open-circuited, although physically connected. Such a condition exists as to currents flowing in phase from the antennas 5 and 7 into the line 11; that is, oscillatory currents flowing in parallel and in time phase to and from the antennas can be considered as inducing voltages in the lines at the axis X—X which are at all times of

equal amplitude and phase. Consequently, at this point, no current flows at any time, and it is, therefore, possible to consider this point as being open-circuited. The assumed condition is, therefore, met and the circuit functions in a manner described to detune the outer antennas and thus substantially reduce the amplitude of the parallel currents in the system.

A further consideration of Fig. 2 shows that the feed points **23** and **25** are each a quarter-wave length from this open end, so that they are effectively short-circuited as to the induced currents flowing in parallel in the system, since a quarterwave line is an impedance inverter. As a result, changes in the transmitter and the transmission lines cannot affect the open circuit condition of the antenna bases as to the parallel currents which flow in what may be termed a parallel mode of oscillation.

When considering the out-of-phase currents flowing in the system from the transmitter, the circulating currents would induce voltages of opposite phase in lines separated at the X—X axis and, consequently, it is essential that the two sections of the line be connected at this point in order to provide a path for these currents; that is, the half-wave lines must be coupled together for currents to flow therebetween in the desired out-of-phase mode of oscillation. The arrangement shown, therefore, effectively isolates the directional antennas **5** and **7** as to an undesired mode of oscillation without affecting their function in the desired mode of oscillation.

Fig. 3 is a perspective view of a directional antenna system suitable for radiating a field of the type used in radio ranges. Omnidirectional antenna **33** is centrally located between four vertical quarter-wave antennas **5**, **7**, **39** and **41**, diagonally opposite antennas being connected together by full-wave lines **11** and **43**, respectively. Each of these lines is identical to the one shown in Fig. 2 and functions in like manner. Connections from the transmitter to each antenna are indicated by the short sections of line which are connected a quarter-wave from the antenna bases. This arrangement is particularly suited for use at ultra high frequencies because the resonant lines become of relatively small dimensions, and make possible a compact structural arrangement. The ground plate **9** may be a metallic disc of a radius equal to an eighth wave length or, preferably, greater, or it may consist of a plurality of rods, or may even comprise the surface of the earth. The connections to the individual antennas are well known, and do not constitute a part of the present invention, and therefore need not be described in detail. The antennas are preferably insulated from the counterpoise at their bases and may be supported in any convenient manner.

The use of a stabilizing line with antennas an even number of quarter wave lengths high is illustrated in Fig. 4. In this embodiment of my invention each antenna **45**, **47**, is a vertical half wave of the conventional type. A concentric half wave stabilizing section **31** is connected between the bases of the antenna at junction points **23**, **25**. The antennas are fed in phase opposition by means of lines **49**, **51** which are also connected to the antennas at their base junction points **23**, **25**. It is to be noted that the quarter wave matching transformers are not included between the antenna bases and the stabilizing section. Such matching transformers may, however, be included in the feed lines **49** and **51** if necessary.

The stabilizing action of line **31** is the same as before. The voltages at the bases of the antennas are maintained in exact phase opposition, and are of equal amplitudes. The line, however, effectively short circuits the base of each antenna as to induced in-phase currents, thus minimizing pickup from the central antenna **33**.

I have thus described a directional antenna system particularly suited for use at high frequencies, which is provided with means for maintaining the currents in oppositely phased antennas in the desired phasal relation, and which also minimizes the coupling between antennas so as to reduce the amplitude of undesired currents flowing in the parallel mode of oscillation.

I claim as my invention:

1. In a high frequency directional antenna system, an array comprising a pair of spaced radiating conductors, means including a half wave concentric feed line for applying energizing currents to said conductors in approximate phase opposition, and stabilizing means including a second half wave concentric line for maintaining said energizing current in one of said conductors in exact phase opposition to the energizing currents in the other of said conductors.

2. In a high frequency directional antenna system, a pair of spaced, vertical radiators, a counterpoise, a concentric feed line having its inner conductor connected between said radiators and its outer conductor connected to said counterpoise, means for applying energizing currents to said radiators in approximate phase opposition through said concentric line, and a half-wave concentric line coupled to said feed line for maintaining the energizing current in one of said radiators in substantial phase opposition to the energizing current in the other of said radiators, and of equal amplitude.

3. In a high frequency directional antenna system, an array comprising a pair of spaced vertical radiators, a source of energizing currents of approximately opposite phase, means coupling said source to said radiators for applying said currents to said radiators, and stabilizing means comprising a resonant line connected across said coupling means for maintaining said currents in phase opposition.

4. In a high frequency antenna system, the combination including a pair of spaced vertical radiators, a source of energizing currents of approximately opposite phase, a pair of quarter-wave transformers coupling said source to said radiators, and stabilizing means connected between the ends of said transformers remote from said radiators.

5. A device of the character described in claim 4 in which said stabilizing means is a concentric half-wave resonator.

6. In a high frequency antenna system, the combination including a pair of spaced vertical radiators, a counterpoise, said radiators being mounted adjacent and perpendicular to said counterpoise, a source of energizing currents of approximately opposite phase, a pair of quarter-wave transformers connected between said source and the ends of respective radiators adjacent said counterpoise, and a concentric half-wave resonator connected between the ends of said transformers remote from said radiators.

7. A device of the character described in claim 6 in which said counterpoise is a metallic disc.

8. In a high frequency antenna system, the

combination including a pair of spaced vertical radiators approximately a quarter-wave long, a counterpoise comprising a conductive surface, said radiators being mounted adjacent and perpendicular to said surface, a source of radio frequency energizing currents of approximately opposite phase for said antenna, a pair of concentric quarter-wave impedance-matching transformers connected between said source and the ends of respective radiators adjacent said surface, and a concentric half-wave resonator connected between the ends of said quarter-wave transformers remote from said radiators.

9. In a high frequency antenna system, a pair of spaced radiators and an intermediate radiator, means for energizing said intermediate radiator, other means for energizing said spaced radiators in relative phase opposition, and means for minimizing the flow of induced in-phase currents from said spaced radiators to said other energizing means independently of the flow of energizing currents to said spaced antennas.

10. In a high frequency antenna system, the combination including a pair of spaced quarter wave vertical antennas and an intermediate quarter wave vertical antenna; means for energizing said intermediate antenna; other means for energizing said spaced antennas in relative phase opposition; and means for minimizing the flow of in-phase currents, induced in said spaced antennas from said intermediate antenna, from said spaced antennas to said energizing means independently of the flow of out-of phase currents from said energizing means to said spaced antennas.

11. A device of the character described in claim 10 which includes, in addition, stabilizing means for maintaining the energizing current in one of said spaced antennas in phase opposition to the energizing current in the other of said spaced antennas.

12. In a high frequency antenna, the combination of an array including a pair of spaced vertical quarter wave antennas and an intermediate antenna, means for energizing said intermediate antenna, a source of energizing currents of approximately opposite phase for said spaced antennas, means coupling said source to said spaced antennas, and stabilizing means connected across said source for maintaining said currents in said spaced antennas in phase opposition.

13. A device of the character described in claim 12 in which said stabilizing means is a half wave resonator.

14. In a high frequency antenna, the combination including a first vertical quarter wave antenna and a pair of spaced quarter wave antennas symmetrically disposed with respect to said first antenna; means for energizing said first antenna; a source of out-of-phase currents for said spaced antennas; a pair of quarter wave matching transformers coupled between said source and said spaced antennas, respectively; and a half wave resonator having its ends connected between the ends of said matching transformers remote from said antennas.

15. A device of the character described in claim 14 in which said matching transformers and said half wave resonator are concentric lines.

16. In a high frequency antenna system, four vertical antennas an odd number of quarter wave lengths in length disposed at the four corners of a square, counterpoise means at the bases of said antennas, a pair of concentric lines a wave length long, opposite ends of said lines being connected between the bases of diagonal pairs of antennas, means for energizing said pairs of antennas in mutual phase opposition, said means including transmission lines connected to said pair of concentric lines at points a quarter wave length from the ends of said lines.

17. A device of the character described in claim 16 which includes, in addition, a fifth vertical antenna and separate means for energizing said fifth antenna.

18. In a high frequency antenna, the combination including a pair of vertical half-wave antennas, means connected to the bases of said antennas for applying energizing currents thereto, and stabilizing means comprising a resonant line interconnecting said antennas for maintaining said energizing currents in phase opposition and of equal amplitudes.

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