May 18, 1948. G. H. BROWN 2,441,615

ANTENNA SYSTEM

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Fig. 1.

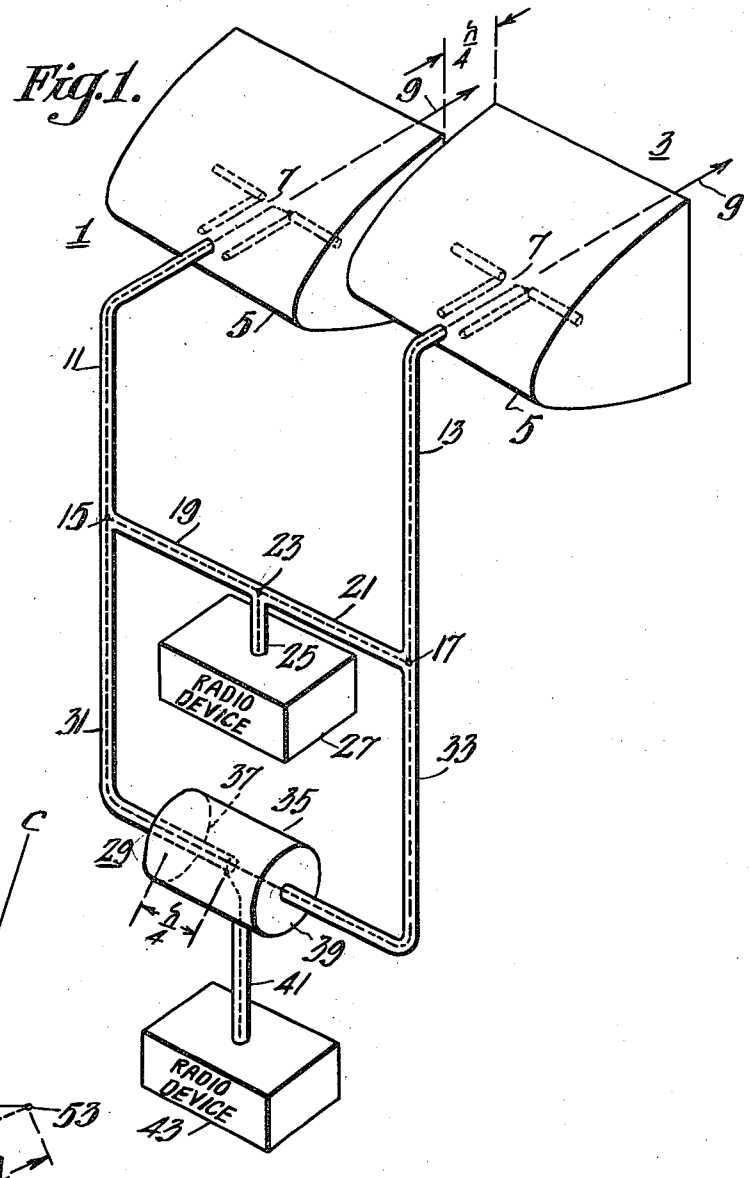
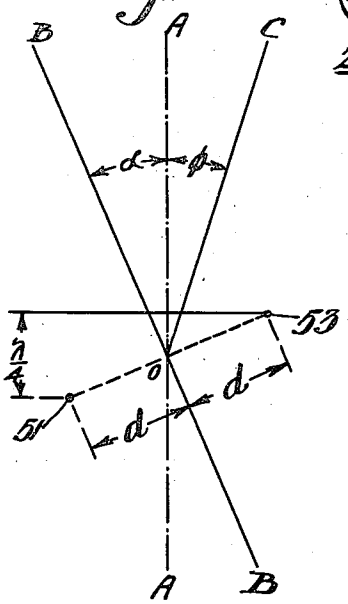


Fig. 2.



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ANTENNA SYSTEM

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11 Claims. (Cl. 250—33.53)

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This invention relates to antenna systems, and more particularly to antennas which may be used for transmission and reception simultaneously of signals of substantially the same frequency. Such antennas are particularly applicable in object detectors and altimeters of the radio reflection type, in which a signal is transmitted, reflected by an object or by the earth, received, and compared with the transmitted signal to determine the signal travel time and hence the distance.

In systems employing a pulsed signal, a single antenna is ordinarily used for both transmission and reception, by switching the antenna to the transmitter each time a pulse is transmitted, disconnecting the receiver. The antenna is connected to the receiver except when the transmitter operates. The switching is usually performed by a so-called "T-R box," which comprises an assembly of resonant-length transmission line sections and one or more gas discharge tubes. One such device is described in copending U. S. application Ser. No. 491,963, filed June 23, 1943, now Patent No. 2,412,315, dated December 10, 1946, by G. H. Brown, and entitled Radio frequency switching system.

Conventional T-R boxes operate more or less satisfactorily with pulsed continuous wave signals, but only at the single carrier frequency for which they are designed. They will not operate with systems of the frequency modulation type, in which a varying frequency signal is constantly transmitted and received.

Heretofore it has been necessary, with frequency modulation radio reflection systems, to use entirely independent antenna systems for transmission and reception. For a given overall directivity, the total space and weight alloted to antennas is considerably greater than that required if a single antenna system is used for both transmission and reception. Furthermore, the two antennas must be isolated from each other, either by spacing them far apart, or by means of trap devices, such as those described in U. S. Patent application Ser. No. 549,241, filed August 12, 1944, by G. H. Brown, and entitled Antenna.

The principal object of the present invention is to provide an improved directive antenna system capable of operation in transmission and reception simultaneously.

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Another object is to provide a system of the described type in which feed-through, or transfer of energy directly between transmitter and receiver, is reduced to a minimum.

A further object is to provide an antenna system of the described type which operates efficiently without substantial feed-through throughout a relatively wide frequency band.

Still another object of the instant invention is to provide an antenna system of the described type which includes few and simple components, requires no critical adjustments, and may be designed easily to fulfill typical performance requirements.

The invention will be described with reference to the accompanying drawing, of which Figure 1 is a schematic diagram of an antenna system embodying the invention, and

Figure 2 is a geometrical diagram illustrating the derivation of the field patterns of the system of Figure 1.

Referring to Figure 1, the radiator portion of the antenna system comprises two directive elements 1 and 3, each comprising a reflector 5 and at least one radiator element 7. The structural details of the elements 1 and 3 are determined in accordance with conventional considerations and otherwise form no part of the present invention, except that the reflectors 5 must be arranged to prevent coupling between the radiator elements. The elements 1 and 3 are positioned with their directive axes parallel to each other, as designated by the arrows 9. The two elements are spaced apart one-quarter wavelength along the direction of their directive axes, the element 3 in the present illustration being in advance of the element 1.

The elements 1 and 3 are provided with feed lines 11 and 13 respectively. The lines 11 and 13 are of equal lengths, terminating at junction points 15 and 17. A pair of branch lines 19 and 21, also of equal lengths, connect the points 15 and 17 to a common fed point 23. The point 23 is connected through a line 25 to a radio device 27, which may be either a transmitter or a receiver. The line 25 may be made of any suitable length.

The junction points 15 and 17 are connected through lines 31 and 33 to a line balance convertor 29. The lines 31 and 33 are of equal

lengths. The convertor 29 comprises a sleeve 35 extending over the final quarter wavelength section of the line 31, and connected to the outer conductor of the line 31, at a point one-quarter wavelength from its end, by a conductive disc 37. A similar disc 39 at the other end of the sleeve 35 is connected to the outer conductor of the line 33. The inner conductors of the lines 31 and 33 are connected together.

A common feed line 41 extends to the convertor 29, with its outer conductor connected to the sleeve 35 and its inner conductor connected to the end of the outer conductor of the line 31. The line 41 is connected to a radio device 43, which may be either a transmitter or a receiver. The line balance convertor 29 is of the type described in copending U. S. application Ser. No. 573,217, filed January 17, 1945, by G. H. Brown, and entitled Line balance convertors. The network including the line sections 19, 21, 31 and 33 and the line balance convertor 29 is of the type described in copending U. S. application Ser. No. 570,682, filed December 30, 1944, by G. H. Brown, and entitled Radio frequency power network.

In the following description of the operation of the system, it is assumed that the radio device 43 is a transmitter. Energy is applied from the device 43 through the line 41 to the line balance convertor 29, causing current to flow in the line 33 in phase with the current in the line 41, and an equal current to flow in the line 31 out of phase with that in the line 41. Thus the points 15 and 17 are fed 180° out of phase with each other by the device 43. Since the lines 11 and 13 are of equal lengths, the radiators 1 and 3 are fed 180° out of phase with each other.

Since the lines 19 and 21 are of equal lengths, the net voltage produced at the junction point 23 by the device 43 is zero, and no energy flows down the line 25 to the device 27, which, in this case, is assumed to be a receiver. Thus feed through from the device 43 to the device 27 is effectively prevented. It is to be understood that the various lines may be made of such lengths and characteristic impedances as to provide proper matching between the device 43 and the radiators 1 and 3, or matching stubs or transformers may be provided at appropriate points in the circuit, in accordance with principles well known to those skilled in the art.

In the operation of the system for reception, radiant energy striking the elements 1 and 3 in such manner as to excite them in phase with each other causes currents to flow down the lines 11 and 13 in phase; these currents add at the point 23 and flow to the device 27. In-phase voltages applied to the balanced input lines 31 and 33 of the convertor 29 are opposed to each other in the convertor, and produce no current in the line 41 to the device 43. Thus assuming that the signals received at the antennas 1 and 3 are such as to excite them equally and in phase, none of the received energy will reach the device 43.

The directive pattern of the antenna of Figure 1 when used for reception is the same as the field pattern would be if the radiators 1 and 3 were energized in phase, for example by connecting a transmitter to the line 25. Referring to Figure 2, the radiators are represented by points 51 and 53, spaced to the left and right respectively of the point 0 on the axis A—A by distances d, with the element 53 displaced ahead of the element 51 along the axis A—A by a distance $\lambda/4$. The individual directive pattern of each radiator, including its reflector, is represented herein as $f(\phi)$, where ϕ is the angle with respect to the axis A—A, and the particular function of ϕ depends upon the design of the radiator and reflector. The arrangement is such that $f(\phi)$ is maximum at $\phi=0$.

With the elements 51 and 53 energized in phase, the field along the line 0—C, at an angle ϕ with respect to the axis A—A, is proportional to:

$$F=f(\phi)\left\{\cos\left[\frac{2\pi d}{\lambda}\sin(\alpha+\phi)\right]+j\sin\left[\frac{2\pi d}{\lambda}\sin(\alpha+\phi)\right]+\cos\left[\frac{2\pi d}{\lambda}\sin(\alpha+\phi)\right]-j\sin\left[\frac{2\pi d}{\lambda}\sin(\alpha+\phi)\right]\right\};$$

$$F=2f(\phi)\cos\left[\frac{2\pi d}{\lambda}\sin(\alpha+\phi)\right]$$

where α is the angle between the axis A—A and the perpendicular bisector B—B of the line between the elements 51 and 53. If the elements 51 and 53 were not displaced along the direction of the axis A—A (i. e. if α were zero), the field along the line 0—C would be proportional to:

$$F=2f(\phi)\cos\left(\frac{2\pi d}{\lambda}\sin\phi\right)$$

and along the line A—A:

$$F=2f(o)\cos 0=2f(o)$$

However, since $\alpha=\sin^{-1}\frac{\lambda/4}{2d}$ (see Figure 2)

$$\sin\alpha=\frac{\lambda/4}{2d}=\frac{\lambda}{8d}$$

and along the axis A—A,

$$F=2f(o)\cos\frac{\pi}{4}=\sqrt{2}f(o)$$

The directive pattern of the system of Figure 1 when used for transmission is that obtained with the radiators 51 and 53 energized out of phase. Referring again to Figure 2, the field at an angle ϕ to the axis A—A is proportional to

$$F'=f(\phi)\left\{\cos\left[\frac{2\pi d}{\lambda}\sin(\alpha+\phi)\right]+j\sin\left[\frac{2\pi d}{\lambda}\sin(\alpha+\phi)\right]-\cos\left[\frac{2\pi d}{\lambda}\sin(\alpha+\phi)\right]+j\sin\left[\frac{2\pi d}{\lambda}\sin(\alpha+\phi)\right]\right\};$$

$$F'=2jf(\phi)\sin\left[\frac{2\pi d}{\lambda}\sin(\alpha+\phi)\right]$$

In this case, if α were zero, the field along the line 0—C would be proportional to:

$$F'=2jf(o)\sin\left(\frac{2\pi d}{\lambda}\sin\phi\right)$$

and along the line A—A:

$$F'=2jf(o)\sin 0=0$$

The reason for displacing the antennas along the direction of the axis A—A should now be apparent. If the antennas are not spaced, the field pattern for the out of phase condition will exhibit a null directly along the axis A—A, and no signal will be transmitted straight ahead, where a maximum signal is desirable. However, with spacing such that

$$\alpha=\sin^{-1}\frac{\lambda}{8d}$$

the field along the axis A—A is

$$F'=2jf(o)\sin\frac{\pi}{4}=j\sqrt{2}f(o)$$

This field is equal in magnitude to the field F, the operator j signifying merely that the fields F and F' are in quadrature.

If the factor $f(\phi)$ were constant, rather than

maximum when $\phi=0$, the field F would exhibit a maximum value along the line B—B, where $\phi=-\alpha$, and the field F′ would exhibit a maximum displaced in the other direction from the axis. The maximum product of the field F and F′ represents the magnitude of the maximum reflected signal which will be received in the operation of the system. This product will be a maximum along the axis A—A, even if $f(\phi)$ is constant. The radiator elements and reflectors may be designed so that the factor $f(\phi)$ decreases rapidly with deviation from the axis A—A, suppressing radiation and reception at angles ϕ differing substantially from zero, and making the pattern shapes for F and F′ substantially identical.

The foregoing analysis applies regardless of which of the devices 27 and 43 of Figure 1 is the transmitter and which is the receiver. Essentially, the present invention contemplates the use of an antenna comprising two independent directive radiator systems, spaced apart one-quarter wavelength along the directive axis, and coupled through a transmission line network in parallel to one utilization device and in push-pull to another utilization device. By this arrangement the two utilization devices are isolated from each other, enabling simultaneous use of the antenna system for both transmission and reception. The quarter wave spacing of the radiator systems together with the use of reflectors, makes the directive patterns for transmission and reception approximately the same. The complete antenna system may be made much less than the size of a system using separate antennas for transmission and reception, with equivalent performance, because the two radiators need not be isolated from each other to prevent feed-through.

I claim as my invention:

1. A radio antenna system including two directive radiator elements disposed with their directive axes parallel with each other and their centers displaced one-quarter wavelength from each other along the direction of said axes, transmission lines connecting both of said radiators to a common feed point in like polarities, and means including transmission lines and a line balance convertor connecting both of said radiators to a second common feed point in unlike polarities.

2. A radio antenna system for simultaneous cooperation with two utilization devices to be electrically isolated from each other, comprising two directive radiator elements disposed with their directive axes parallel with each other, said elements being spaced one-quarter wavelength from each other along the direction of said axes, means connecting both of said elements to one of said devices in like polarities, and means including a line balance convertor connecting both of said elements to the other of said devices in unlike polarities.

3. A radio antenna system for simultaneous cooperation with two utilization devices to be electrically isolated from each other, comprising two directive radiator elements disposed with their directive axes parallel with each other, said elements being spaced from each other along the direction of said axes, transmission lines connecting said elements to one of said devices in like polarities, and transmission lines and line balance convertor means connecting both of said elements to the other of said devices in unlike polarities.

4. A radio antenna system including two directive radiator elements disposed with their directive axes parallel to each other and their centers displaced from each other along the direction of said axes, a pair of transmission lines each connecting one of said radiators to a respective junction point, a second pair of transmission lines each connecting one of said junction points to a common feed point, a line balance convertor, a third pair of transmission lines each connecting one of said junction points to balanced terminals of said convertor, the unbalanced terminals of said convertor constituting a second common feed point.

5. A radio antenna system including two directive radiator elements disposed with their directive axes parallel to each other and their centers displaced one-quarter wavelength from each other along the direction of said axes, a pair of transmission lines, each connecting one of said radiators to a respective junction point, a second pair of transmission lines, each connecting one of said junction points to a common feed point, a line balance convertor, a third pair of transmission lines, each connecting one of said junction points to balanced terminals of said convertor, the unbalanced terminals of said convertor constituting a second common feed point.

6. A radio antenna system including two directive radiator elements disposed with their directive axes parallel to each other and their centers displaced from each other along the direction of said axes, a pair of transmission lines of equal lengths, each connecting one of said radiators to a respective junction point, a second pair of transmission lines of equal lengths, each connecting one of said junction points to a common feed point, a line balance convertor, a third pair of transmission lines of equal lengths each connecting one of said junction points to balanced terminals of said convertor, the unbalanced terminals of said convertor constituting a second common feed point.

7. A radio antenna system including two directive radiator elements disposed with their directive axes parallel to each other and their centers displaced one-quarter wavelength from each other along the direction of said axes, a pair of transmission lines of equal lengths, each connecting one of said radiators to a respective junction point, a second pair of transmission lines of equal lengths, each connecting one of said junction points to a common feed point, a line balance convertor, a third pair of transmission lines of equal lengths each connecting one of said junction points to balanced terminals of said convertor, the unbalanced terminals of said convertor constituting a second common feed point.

8. A radio antenna system including two directive radiator elements with directive axes parallel to each other, said elements being displaced from each other along the direction of said axes, a common feed line, a pair of branch feed lines connected from said common feed line to said elements respectively, a second common feed line, a line balance convertor connected to said second common feed line, and a second pair of branch feed lines connected from said line balance convertor to said elements respectively, whereby said elements are electrically in parallel with each other in one polarity across said first common feed line and electrically in series with each other in the opposite polarity across said second common feed line.

9. A radio antenna system including two directive radiator elements with directive axes parallel to each other, said elements being displaced from each other one-quarter wavelengths along the direction of said axes, a common feed line, a

pair of branch feed lines connected from said common feed line to said elements respectively, a second common feed line, a line balance convertor connected to said second common feed line, and a second pair of branch feed lines connected from said line balance convertor to said elements respectively, whereby said elements are electrically in parallel with each other in one polarity across said first common feed line and electrically in series with each other in the opposite polarity across said second common feed line.

10. A radio antenna system including two directive radiator elements with directive axes parallel to each other, said elements being displaced from each other along the direction of said axes, a common feed line, a pair of branch feed lines of equal lengths connected from said common feed line to said elements respectively, a second common feed line, a line balance convertor connected to said second common feed line, and a second pair of branch feed lines of equal lengths connected from said line balance convertor to said elements respectively, whereby said elements are electrically in parallel with each other in one polarity across said first common feed line and electrically in series with each other in the opposite polarity across said second common feed line.

11. A radio antenna system including two directive radiator elements with directive axes parallel to each other, said elements being displaced one-quarter wavelength from each other along the direction of said axes, a common feed line, a pair of branch feed lines of equal lengths connected from said common feed line to said elements respectively, a second common feed line, a line balance convertor connected to said second common feed line, and a second pair of branch feed lines of equal lengths connected from said line balance convertor to said elements respectively, whereby said elements are electrically in parallel with each other in one polarity across said first common feed line and electrically in series with each other in the opposite polarity across said second common feed line.

GEORGE H. BROWN.

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The following references are of record in the file of this patent:

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