

May 21, 1946.

G. H. BROWN

2,400,736

ANTENNA SYSTEM

Filed Sept. 30, 1941

3 Sheets-Sheet 1

FIG. 1.

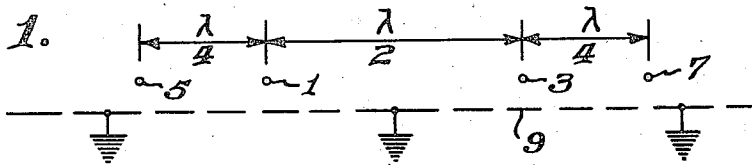


FIG. 2.

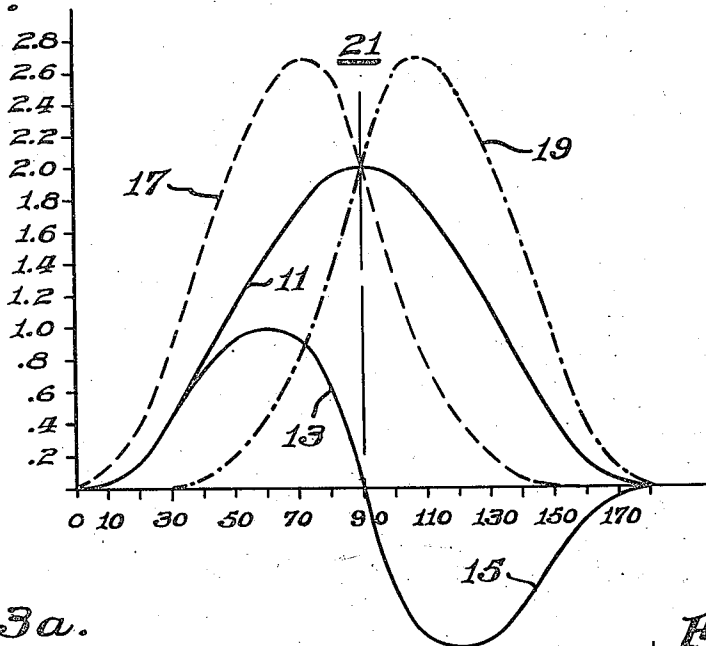


FIG. 3a.

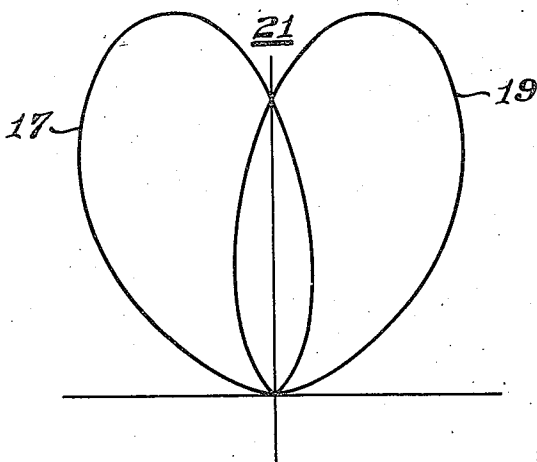
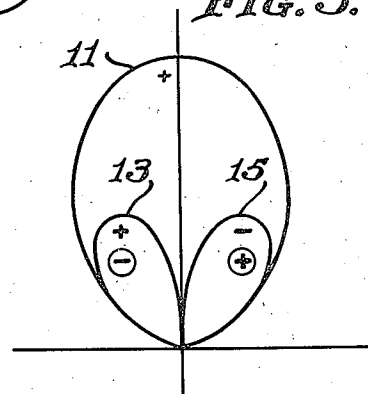


FIG. 3.



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FIG. 4.

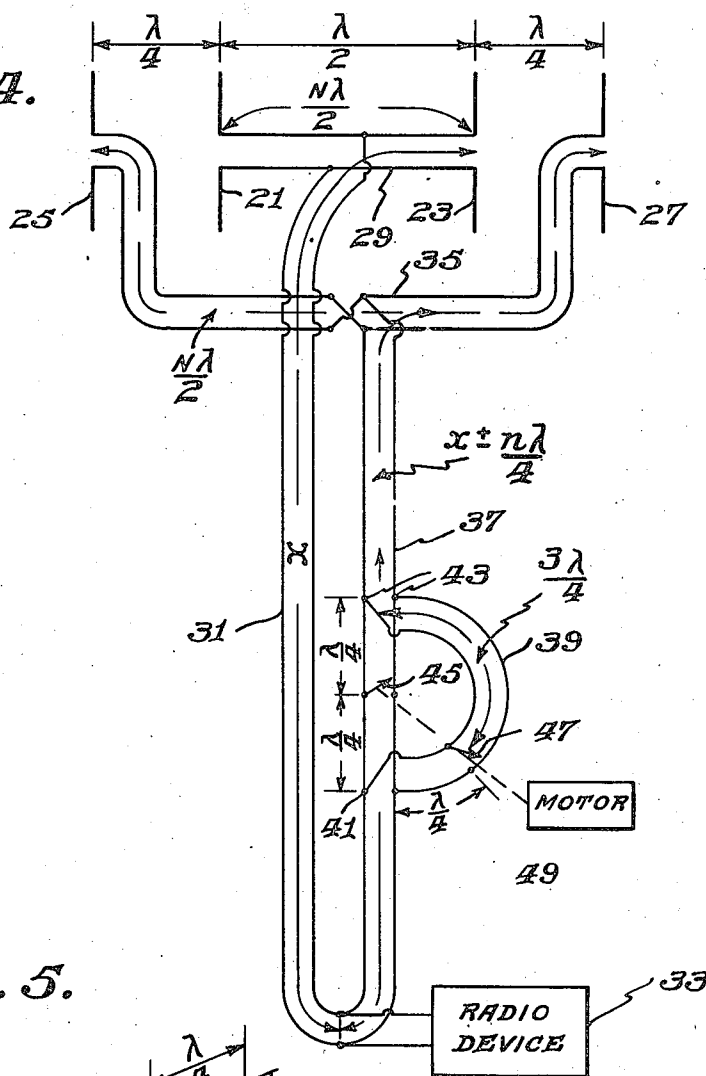
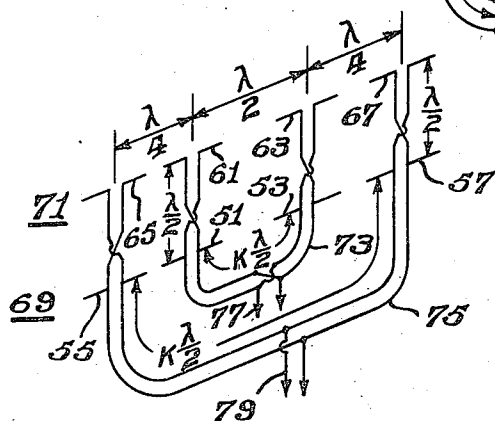


FIG. 5.



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FIG. 6.

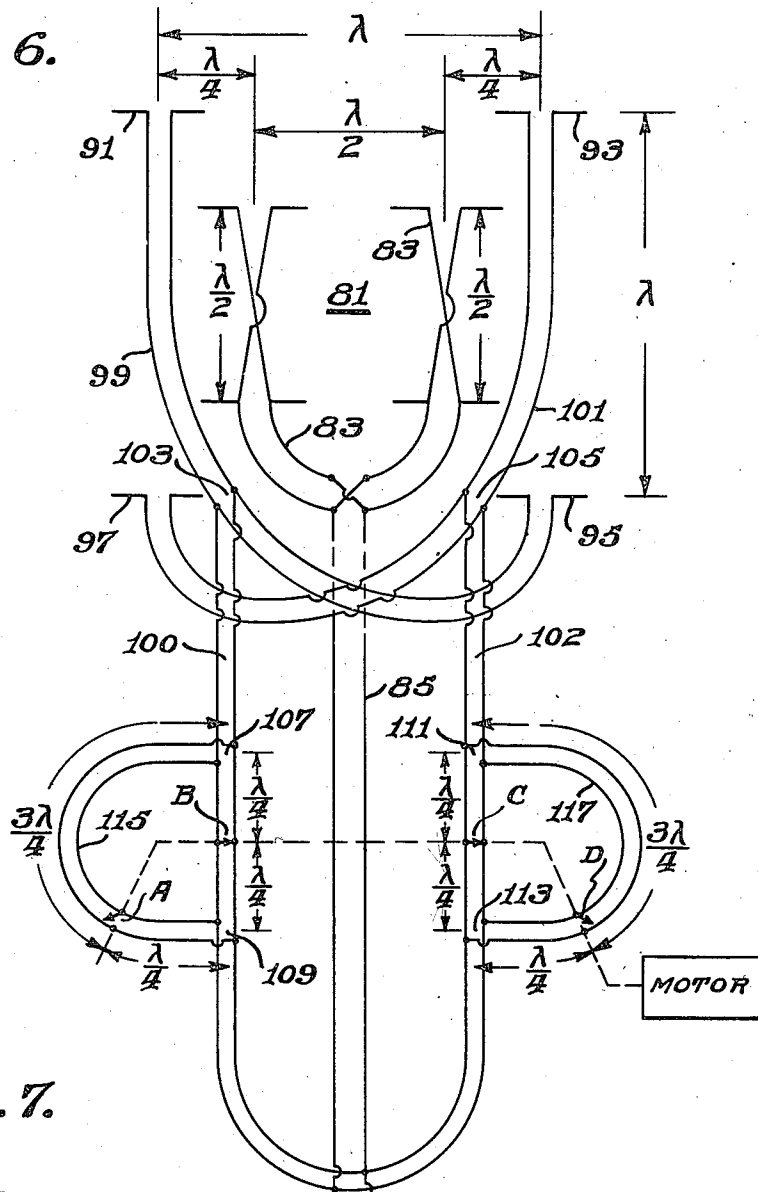


FIG. 7.

SWITCHES				RELATIVE PHASE ANT. CURRENTS	RESULTANT FIELD
A	B	C	D		
↗	↗	↗	↗	→	→
↖	↖	↖	↖	←	←
↗	↖	↗	↖	↗	↗
↖	↗	↖	↗	↖	↖
↗	↗	↖	↖	↗	↗
↖	↖	↗	↗	↖	↖

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UNITED STATES PATENT OFFICE

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ANTENNA SYSTEM

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Application September 30, 1941, Serial No. 412,943

19 Claims. (Cl. 250-11)

This invention relates to improvements in antenna systems of the type used to establish overlapping fields, and particularly to an antenna system in which simple, inexpensive arrangements are used to minimize the mutual coupling between several antennas of an array and to reverse alternately the phase of the currents applied to one pair of antennas with respect to the phase of the currents of another pair of antennas, whereby differently directed field patterns are obtained in synchronism with said phase reversal.

Numerous arrangements of antennas have been described for obtaining differently directed and overlapping field patterns. In many such arrangements the desired fields are accompanied by undesired subsidiary lobes which deleteriously affect the utility of the system. In systems utilizing the overlapping fields it may be necessary to establish the fields alternately, and this often requires complicated and expensive switching mechanism. Moreover, many such systems require a series of critical measurements and adjustments which often interact on each other and require further adjustments.

One of the objects of the instant invention is to provide improved means for establishing alternately differently directed and overlapping radio frequency fields. Another object is to provide an improved antenna system in which the antennas are arranged to minimize mutual coupling and in which the antennas are energized with currents alternately phased to produce a pair of differently directed fields having an overlapping portion. An additional object is to provide means whereby an antenna array, for radiating alternately differently directed and overlapping fields, may be assembled at predetermined spacings with predetermined lengths of transmission line and without a series of critical measurements and adjustments.

The invention will be described by referring to the accompanying drawings, in which Fig. 1 is a diagram of an antenna array employed in one embodiment of the invention; Fig. 2 is a graph illustrating the field patterns of the array; Figs. 3 and 3A are graphs of the field patterns in polar coordinates; Fig. 4 is a circuit diagram of a simplified embodiment; Fig. 5 is a circuit diagram of a preferred embodiment of the invention; Fig. 6 is a circuit diagram of an embodiment of the invention employing four way switching; and Fig. 7 is a graph illustrating the operation of the four way switching.

Referring to Fig. 1, a pair of dipole antennas 1, 3, which may be vertically or horizontally polar-

ized, are spaced a half wave length at the operating frequency. A second pair of dipoles 5, 7, which are polarized to correspond with the first pair, are spaced apart a full wave length and respectively a quarter wave length from the first dipoles and substantially in alignment with the first pair. A grounded screen 9 is placed parallel to and behind the antennas to suppress radiation in the direction of the screen. In some installations bidirectional radiation may be desired; if so, the screen may be omitted.

If the first pair of antennas 1, 3 are energized in phase and if the screen 9 is omitted, a figure-of-eight field of radiation will be established. In the presence of the screen 9 the radiation field from the first pair of antennas will be a single lobe as represented by the curve 11 of Fig. 3, and may be indicated by the equation

$$F=K(2\cos(90^\circ\cos\phi))$$

where

F=field strength,

K=a proportionality constant,

and

ϕ =angle from the plane of antennas.

If the second pair of antennas 5, 7 are energized in opposite phase and if the screen 9 is omitted, a four-lobe field of radiation will be established. In the presence of the screen 9, the radiation field from the second pair of antennas will be a pair of lobes represented by the curves 13, 15 of Fig. 3. Currents of quadrature phase, with respect to the currents in the first pair of antennas, are applied to the second pair of antennas and the currents in the second pair are made of a magnitude at which the maximum strength of each of the two lobe fields 13, 15 is half the maximum strength of the single lobe field 11. The equation representing the two lobe fields may be indicated by

$$F=K(\sin(180^\circ\cos\phi))$$

where

F=field strength,

K=a proportionality constant,

and

ϕ =angle from plane of antennas.

The resultant fields may be represented by the curve 17 of Fig. 3A. This curve is obtained by combining the curves 11, 13 and 15.

If the phase of the currents applied to the second pair of antennas is reversed with respect to the phase of the currents applied to the first pair, or vice versa, the fields 11, 13 and 15 will again be in phase but will have opposite instan-

taneous polarities as indicated by the polarity marks within the circles. The resultant field is indicated by the curve 21 of Fig. 3A. The resultant equation of the fields 17 and 19 is as follows:

$$F = K 2 \cos(90^\circ \cos \phi) \pm \sin(180^\circ \cos \phi)$$

For convenience, the curves 11, 13, 15, 19, 21 have been reproduced in Fig. 2, which is plotted in rectangular coordinates. Similar reference characters indicate similar curves in the several graphs. The curve representing the reversal in phase indicated by the polarity marks in the circles has been omitted from Fig. 2 to avoid confusion. It should be understood that the omitted curve would correspond in magnitude and shape to the curves 13, 15 and would be reversed in sign.

The circuit arrangements are shown in Fig. 4, in which the first pair of dipoles 21, 23 are spaced a half wave length from each other and the second pair of dipoles 25, 27 are respectively spaced a quarter wave length from the dipoles of the first pair. Mutual coupling between the first dipoles 21, 23 is avoided by means of a transmission line 29, which has a length equal to an even multiple of a half wave length, or

$$\frac{N\lambda}{2}$$

where N is an even integer and λ = the wave length of the applied currents. The transmission line 29 neutralizes the mutual coupling which would otherwise exist between the dipoles 21, 23. A second transmission line 31, of length X, measured from one of the dipoles 23, is connected from the mid-point of the first line 29 to a radio device 33 which may be either a transmitter or a receiver. If the device 33 is a transmitter, it applies in phase currents to the first pair of dipoles.

The second pair of dipoles are connected by a transposed transmission line 35, which is an even number of half wave lengths long. This line length is chosen to neutralize the mutual coupling between the connected dipoles 25, 27 and the pairs of adjacent dipoles 21—25 and 23—27. The line 35 is transposed to reverse the phase of the currents in the two dipoles 25 and 27. The mid-point of the transposed line 35 is connected to the device 33 through a transmission line 37, which has a length (measured from one of the dipoles 27) differing from X by an odd number of quarter wave lengths. The length

$$X \pm \frac{n\lambda}{4}$$

where X is the length of the previously mentioned line 31 and n is any odd integer, makes the phase of the currents applied to the second pair of dipoles differ by 90° from the phase of the currents applied to the first pair of dipoles. This is a condition which is necessary if the fields from the several antennas are to be in phase or out of phase, so that they may be combined to produce the desired resultant patterns.

In devices employing overlapping fields, it is usual to radiate the fields in alternately different directions. For example, the patterns 17 and 19 are established alternately so that the region of equal signal strengths may be employed to define a course or direction. One suitable means for establishing the alternate fields is to connect a full wave transmission line 39 across terminals 41, 43 spaced a half wave along the line 37. A pair of short circuit devices, such as

switches 45, 47, are connected at quarter wave lengths from the terminals 41 across the line 37 and across the line 39. These switches 45, 47 are arranged to short circuit alternately and may be driven by a motor 49. When the switch 47 is open and the switch 45 is closed, the line 37 between the terminals 41, 43 becomes a high impedance so that the antenna currents flow through the full wave section 39. When the switch 45 is open and the switch 47 is closed, the line 39 becomes a high impedance so that the antenna currents flow directly through the line 37. Since the full wave line 39 is a half wave longer than the section between the terminals 41, 43, it follows that the phase of the currents is reversed alternately in synchronism with the switching. In place of conductive switching, capacitor switching of the type described in a copending application Serial No. 412,291, filed Sept. 25, 1941 by William D. Hersberger for "Antenna switching systems," may be used.

A preferred antenna array is illustrated in Fig. 5. In this array the several antennas are horizontally arranged dipoles. In addition to the first and second pairs 51, 53, and 55, 57, two or more pairs of dipoles 61, 63 and 65, 67 are connected with the correspondingly spaced dipoles connected in parallel. The space between the dipoles of the first and second rows 59, 71 is made a half wave length. This arrangement sharpens the directivity in the vertical plane. The pairs of antennas in the two rows are connected with transmission lines 73 and 75 which correspond, respectively, to the lines 29 and 35 previously described. The transmission lines 73 and 75 are connected through a pair of lines 77, 79 to a radio device (not shown). The lines between the dipoles and the radio device are arranged in the manner of the lines 31 and 37 of Fig. 2. The switching device may be used to reverse the phase of the applied currents, as disclosed above.

In describing the invention several antenna arrays have been used as illustrations; it should be understood that the invention may be applied to other arrays. The dipole radiators may be replaced by the type of radiator disclosed in Fig. 1 of copending application Serial No. 361,494, filed October 17, 1940, by Jess Epstein, for "Turnstile antennas." If this type of radiator is used, the mutual coupling will not be neutralized by transmission lines of even numbers of half wave lengths, but neutralization will be effected by using lines of odd numbers of half wave lengths.

The antenna system illustrated in Fig. 5 lends itself to four-way switching for establishing four differently directed fields having a mutually overlapping portion. The switching arrangement used in connection with Fig. 5 directs the resultant fields to the right and left of a vertical plane normal to the grounded screen 9. If the phases of the applied currents are suitably switched, the resultant field may be directed "up and down" as well as to the "right and left." This may be visualized by considering the antenna array of Fig. 1 mounted vertically so that the lobes 17 and 19 of Fig. 3 are directed downwardly and upwardly. Then imagine the orientation in the horizontal plane with the lobes 17 and 19 directed to left and right. One suitable arrangement for such "four way switching" is shown in Fig. 6.

In Fig. 6 the central antenna 81 consists of four dipoles, arranged at the corners of a square which is a half wave length on a side. The

dipole connections are transposed so that all of the dipoles are fed in phase. The lengths of the connecting lines 83 are chosen to neutralize undesired mutual coupling. The transmission line 85 from the central antenna to the radio device 87 is of a length which provides a 90° phase shift to the central antenna currents with respect to the currents applied to four subsidiary antennas 91, 93, 95 and 97. The subsidiary antennas are symmetrically located with respect to the central antenna, are similarly polarized, and are located at the corners of a square which is a wave length on each of its sides. The diagonally disposed subsidiary antennas 91, 95 and 93, 97 are connected together by transmission lines 99, 101 which have lengths chosen for neutralization of undesired mutual antenna coupling. The diagonally connected lines 99, 101 are connected from their mid-electrical terminals 103, 105 to the radio device 87. Phase reversing elements, consisting of full wave lines 115, 117, are connected between points 107, 109 and 111, 113, spaced a half wave length on each of the lines 100, 102.

The phase of the antenna currents of each antenna of the subsidiary antennas is reversed with respect to the currents of its adjacent antenna by connecting switches A, B, C and D between terminals a quarter wave length from the points 109 and 113. The four switches are arranged to operate in the sequence illustrated in Fig. 7 so that the antenna currents are reversed in phase in the subsidiary antennas whereby the resultant fields are directed in four regions having a mutual overlapping region.

The diagram shows (1) the several switches in their several operating combinations; (2) the relative phases of the subsidiary antenna currents by a convention of vectors and the central antenna current by a dot; and (3) the resultant fields by arrows indicating not absolute direction of the fields, but the departure of the resultant fields from a central axis.

The capacitor type of switch with sections disposed in 90° relation forms a convenient and practical switching device. The theory of operation of the switching lines is similar to that described in connection with the circuit of Fig. 5. It should be understood that a cam operated switch may be used. Furthermore, an antenna array may be substituted for each dipole antenna to increase the directivity of the resultant pattern.

Thus the invention has been described as an antenna system in which several antennas are suitably spaced from each other. The several antennas are energized in relative phases which establish a desired directional radiation pattern. The mutual coupling between the several antennas is neutralized by means of transmission lines of critical lengths. Other lines of suitable length determine the relative phases of the applied currents so that differently directed and overlapping patterns are alternately created. The resultant patterns are free from undesired secondary lobes.

I claim as my invention:

1. An antenna system for establishing overlapping directive fields including a source of radio frequency power, a first pair of directive antennas spaced a half wave length at the operating frequency, a second pair of directive antennas spaced a wave length at the operating frequency and located in substantial alignment with and respectively a quarter wave length on either side

of the antennas of said first pair, means for applying current from said source to said first pair of antennas in the same phase, and means for applying current from said source to said second pair of antennas in phase opposition and in quadrature phase with respect to the currents in said first pair of antennas.

2. An antenna system for establishing overlapping directive fields including a source of radio frequency power, a first pair of dipole antennas spaced a half wave length at the operating frequency, a second pair of dipole antennas spaced a wave length at the operating frequency and located in substantial alignment with and respectively a quarter wave length on either side of the antennas of said first pair, means for applying current from said source to said first pair of antennas in the same phase, and means for applying current from said source to said second pair of antennas in phase opposition and in quadrature phase with respect to the currents in said first pair of antennas.

3. An antenna system for establishing overlapping directive fields including a source of radio frequency power, a first pair of directive antennas spaced a half wave length at the operating frequency, a second pair of directive antennas spaced a wave length at the operating frequency and located in substantial alignment with and respectively a quarter wave length on either side of the antennas of said first pair, means for applying current from said source to said first pair of antennas in the same phase, means for applying current from said source to said second pair of antennas in phase opposition and in quadrature phase with respect to the currents in said first pair of antennas, and a grounded screen located parallel to the plane of said antennas for suppressing the radiation in the direction of the screen.

4. An antenna system for establishing overlapping directive fields including a source of radio frequency power, a first pair of dipole antennas spaced a half wave length at the operating frequency, a second pair of dipole antennas spaced a wave length at the operating frequency and located in substantial alignment with and respectively a quarter wave length on either side of the antennas of said first pair, means for applying current from said source to said first pair of antennas in the same phase, means for applying current from said source to said second pair of antennas in phase opposition and in quadrature phase with respect to the currents in said first pair of antennas, and a grounded screen located parallel to the plane of said antennas for suppressing the radiation in the direction of the screen.

5. An antenna system for establishing overlapping directive fields including a source of radio frequency power, a first pair of directive antennas spaced a half wave length at the operating frequency, a second pair of directive antennas spaced a wave length at the operating frequency and located in substantial alignment with and respectively a quarter wave length on either side of the antennas of said first pair, means for applying current from said source to said first pair of antennas in the same phase, means for applying current from said source to said second pair of antennas in phase opposition and in quadrature phase with respect to the currents in said first pair of antennas, and means for minimizing the mutual couplings between said antennas.

6. An antenna system for establishing over-

lapping directive fields including a source of radio frequency power, a first pair of directive antennas spaced a half wave length at the operating frequency, a second pair of directive antennas spaced a wave length at the operating frequency and located in substantial alignment with and respectively a quarter wave length on either side of the antennas of said first pair, means for applying current from said source to said first pair of antennas in the same phase, means for applying current from said source to said second pair of antennas in phase opposition and in quadrature phase with respect to the currents in said first pair of antennas, and means for reversing alternately the phase of the currents of the antennas of one of said pairs with respect to the phase of the currents of the other of said pairs whereby differently directed radiation patterns are obtained in synchronism with said phase reversals.

7. An antenna system according to claim 6 including means for minimizing the mutual couplings between said antennas.

8. An antenna system according to claim 6 including a grounded screen located parallel to the plane of said antennas for suppressing the radiation in the direction of the screen.

9. An antenna system according to claim 6 including means for minimizing the mutual couplings between said antennas and a grounded screen located parallel to the plane of said antennas for suppressing the radiation in the direction of the screen.

10. An antenna system for establishing overlapping directive fields including a source of radio frequency power, a first pair of directive antennas spaced a half wave length at the operating frequency, a second pair of directive antennas spaced a wave length at the operating frequency and located in substantial alignment with and respectively a quarter wave length on either side of the antennas of said first pair, means for applying current from said source to said first pair of antennas in the same phase, means for applying current from said source to said second pair of antennas in phase opposition and in quadrature phase with respect to the currents in said first pair of antennas, means for reversing alternately the phase of the currents of the antennas of one of said pairs with respect to the phase of the currents of the other of said pairs so that differently directed patterns are obtained in a predetermined plane in synchronism with said phase reversals, and additional means for sharpening each of said differently directed patterns in a plane normal to said predetermined plane.

11. An antenna system according to claim 10 including means for minimizing the mutual couplings between said antennas.

12. An antenna system according to claim 10 including a grounded screen located parallel to the plane of said antennas for suppressing the radiation in the direction of the screen.

13. An antenna system according to claim 10 including means for minimizing the mutual couplings between said antennas and a grounded screen located parallel to the plane of said an-

tennas for suppressing the radiation in the direction of the screen.

14. An antenna system for establishing overlapping directive fields including a source of radio frequency power, a first pair of dipole antennas spaced a half wave length at the operating frequency, a second pair of dipole antennas spaced a wave length at the operating frequency and located in substantial alignment with and respectively a quarter wave length on either side of the antennas of said first pair, means for applying current from said source to said first pair of antennas in the same phase, means for applying current from said source to said second pair of antennas in phase opposition and in quadrature phase with respect to the currents in said first pair of antennas, means for reversing alternately the phase of the currents applied to one pair of antennas with respect to the phase of the currents applied to the other pair of antennas so that the resultant fields overlap in synchronism with said phase reversals and form a region in which the signal strengths are equal.

15. An antenna system including in combination a central antenna, four subsidiary antennas symmetrically located with respect to said central antenna, means for applying currents to said antennas including a phase shifter for applying currents to said central antenna in phase quadrature with respect to currents applied to said four subsidiary antennas, and switching means for reversing the phase of the currents applied to each subsidiary antenna with respect to the phase of the currents applied to its adjacent subsidiary antenna so that four resultant radiation fields are established in four regions including a mutual overlapping region.

16. An antenna system including in combination a central antenna, four subsidiary antennas symmetrically located with respect to said central antenna, all of said antennas having the same polarization and lying in substantially the same plane, means for applying currents to said antennas including a phase shifter for applying currents to said central antenna in phase quadrature with respect to currents applied to said four subsidiary antennas, and switching means for reversing the phase of the currents applied to each subsidiary antenna with respect to the phase of the currents applied to its adjacent subsidiary antenna so that four resultant radiation fields are established in four regions including a mutual overlapping region.

17. An antenna system according to claim 15 including means for neutralizing the effect of mutual coupling between said antennas.

18. An antenna system according to claim 15 including a grounded screen located parallel to said antennas for suppressing radiation in the direction of the screen.

19. An antenna system according to claim 15 including means for neutralizing the effect of mutual coupling between said antennas and a grounded screen located parallel to said plane for suppressing radiation in the direction of said screen.

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