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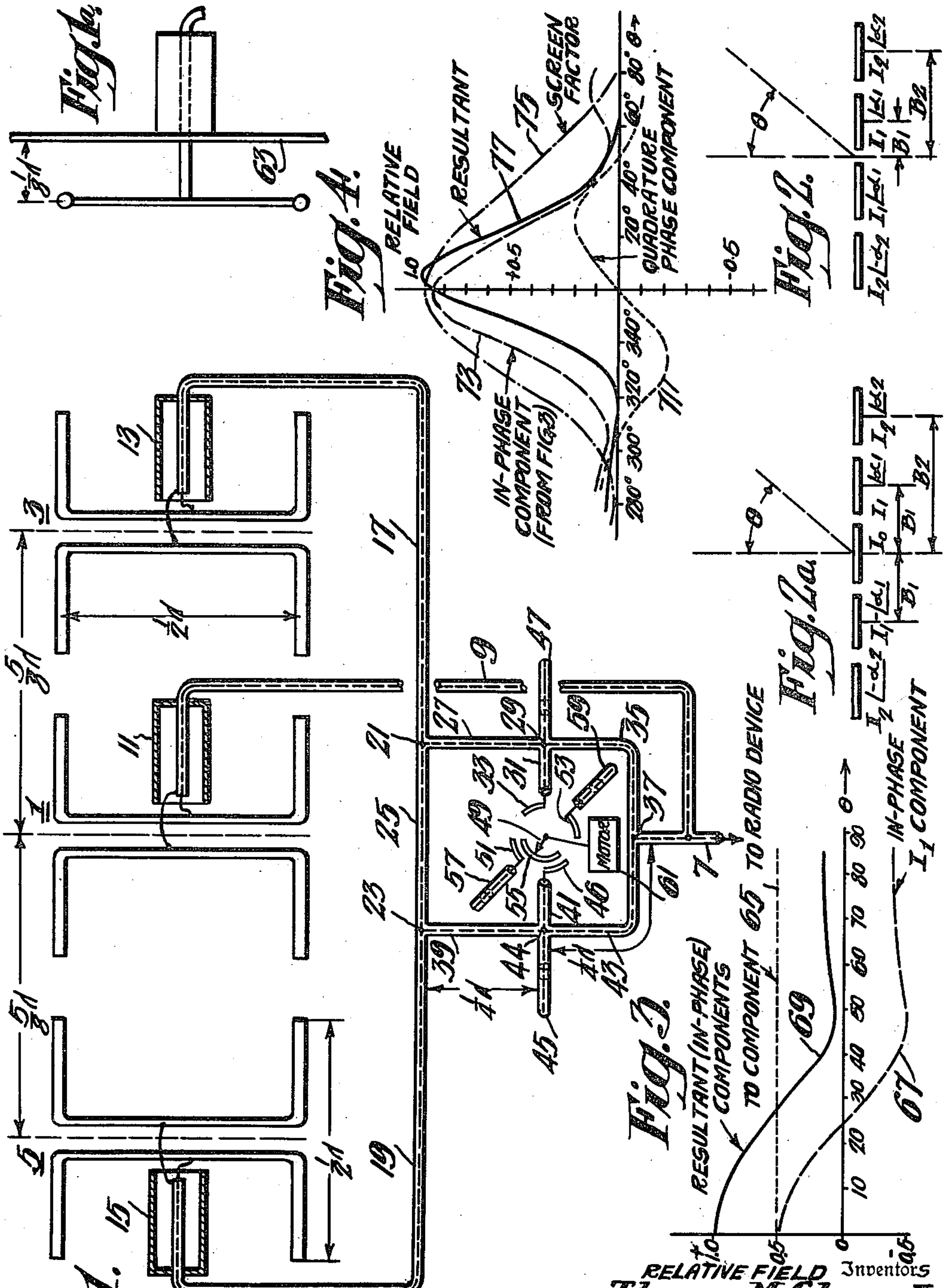

RELATIVE FIELD

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LOBE SWITCHING ANTENNA

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This invention relates to directive antennas and more particularly to an antenna system for providing alternately overlapping directive lobes. In some applications it is desirable to radiate or pick up energy alternately in two relatively narrow overlapping lobes. This may be accomplished by an array of spaced dipoles energized or coupled together in such phase relationships that the resultant directive pattern comprises a beam whose axis may be shifted by suitable variation of the phase relationships between the several elements. In such applications as require two discrete lobes, without any intermediate directivity, the changes in phasing may be provided by a switching mechanism of some sort. The arrays used for this purpose generally comprise at least one central group of radiating elements, and one or more groups of side elements disposed symmetrically with respect to said central group and phased in opposite senses with respect to said central group so as to provide an additive effect on one side of the axis of the array and a subtractive effect on the other side. The problem of switching radio frequency energy, particularly when relatively large peak power is involved, has been met to some extent by the employment of capacitor type switches, thus avoiding movable make-and-break contacts. Another problem which arises in the design and operation of directive arrays of the above described type is the elimination of undesired secondary lobes in the radiation pattern. In order to achieve the desired sharpness of directivity while avoiding secondary lobes it is usually necessary to use an array comprising a large number of elements, and on ship board and in other mobile installations there is usually a definite limit to the size of the array which can be tolerated.

It is the principal object of the present invention to provide an improved method of and means for providing alternately overlapping radiation directive patterns.

Another object is to provide a directive antenna array for the above purpose which is relatively simple and compact in construction.

A further object is to provide an improved method of and means for changing the energization of the various elements of an antenna array for the purpose of controlling the directive pattern thereof.

A further object is to provide an improved capacitor type switch.

These and other objects will become apparent to those skilled in the art upon consideration of the following description with reference to the accompanying drawing, of which Fig. 1 is a schematic diagram of an antenna array and its associated circuits arranged according to the present invention, Fig. 1*a* is a side view of a radiating element mounted in front of a screen, Figs. 2 and 2A are schematic diagrams of antenna arrays explanatory of the operation of the system of Fig. 1, Fig. 3 is a group of curves representing the components of a radiation field produced by the effect of the in-phase currents in the system of Fig. 1, and Fig. 4 is a group of curves illustrating the production of the directive field by all of the currents in the system of Fig. 1.

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Referring to Fig. 1, the antenna array to be described comprises a central group 1 of radiator elements and two side groups 3 and 5, symmetrically located with respect to the central group. A concentric line 7 is connected to a radio device, not shown, which may be a receiver, a transmitter, or both. The line 7 is connected directly by a concentric line 9 to the central group 1. In order to convert from the electrically unsymmetrical concentric line to a circuit which is symmetrical with respect to the ground, suitable for connection to dipole antenna elements, a concentric line transformer 11 is provided. This device comprises a relatively large cylindrical conductive section ¼ wave length long, connected at its base to the outer conductor of the line 9. The central group comprises two parallel dipoles spaced apart ½ wave length and connected in parallel as shown. Each of the side groups comprises a similarly arranged pair of dipoles. The center line of each side group is ⅝ wave length from that of the central group. The side groups 3 and 5 are coupled through concentric line transformers 13 and 15 and lines 17 and 19 respectively to the switching circuit at the junction points 21 and 23. The points 21 and 23 are connected together by a line 25 of a length equivalent to 50 electrical degrees. The point 21 is connected through a line 27, ¼ wave length long, to a junction point 29. The point 29 is connected through a line 31 to a stationary capacitor plate 33 and through a ¼ wave line 35 to a junction point 37. The junction point 23 is similarly connected through a ¼ wave line 39 and lines 41 and 43 to a stator plate 46 and to the junction 37. A stub line 45 is connected to the junction point between the lines 39, 41 and 43 and a similar stub 47 is connected to the opposite junction point 29. The capacitor switch 49 includes the stator plates 33 and 46, a pair of stator plates 51 and 53, and a single rotor plate 55. The stator plates 51 and

53 are connected to stub lines **57** and **59** respectively. The rotor plate **55** is mechanically connected to a motor **61** provided with a suitable power supply, not shown.

Referring to Fig. 2, the radiation from pairs of radiators along a line symmetrically disposed with respect to the midpoint of the line is of the form:

$$\text{Field}=K(I_1 \cos (B_1 \sin \theta+\alpha_1)+I_2 \cos (B_2 \sin \theta+\alpha_2)+\ .\ .\ .)$$

Where K is a constant, I_1, I_2 . . . are the radiator currents, of phase angles α_1, α_2 . . ., and B_1 B_2 . . . are the radiator spacings in radians.

For an add number of radiators (Fig. 2A):

$$\text{Field}=K[0.5I_0+I_1 \cos (B_1 \sin \theta+\alpha_1)+I_2 \cos (B_2 \sin \theta+\alpha_2)\ .\ .\ .]$$

The actual field pattern may be determined by multiplying the above expression by the directivity pattern of the radiator element, including the effect of the reflecting screen. This factor may be determined experimentally with a single radiator element. In the array of Fig. 1 the dipole elements are supported ⅛ wave length in front of a screen **63**, as illustrated in Fig. 1A. When the array is used for transmitting, the current in the central group is maintained constant. The current in each element of the side group is ½ that of each element of the central group, and in one position of the switch **49**, the current in the side group **3** leads the current in the center group **1** by 25°. The current in the side group **5** lags that in the central group by the same amount. For the opposite position of the switch **49** these conditions are reversed, and the current in the side group **5** leads while that of the side group **3** lags.

Referring to Fig. 3, the field components resulting from the in-phase components of the antenna currents are illustrated. This figure neglects the individual directivity of the radiators and the effect of the screen which will be taken into account in Fig. 4. The field component caused by the central antenna is represented by the dotted line **65**. This is seen to be independent of the bearing angle θ. The field component produced by the currents in the side groups **3** and **5** is indicated by the dash line **67**. This is a function of the angle θ as described above. It is to be understood that the curve **67** represents only that portion of the field which is produced by the in-phase components of the currents in the antennas. The resultant field is merely the sum of the fields produced by the side and center groups and is thus represented by the solid line curve **69**.

Referring to Fig. 4, the resultant due to the quadrature phase components of the side antenna currents is represented by the dotted line **71**. The resultant field caused by the in-phase components, represented by the curve **69** in Fig. 3, is shown by the dash line curve **73** in Fig. 4. This curve is equivalent to the curve **69** but is represented on a different scale and is extended to both sides of the zero bearing axis. The directivity factor produced by the use of a screen and the directivity of the individual radiators is represented by the alternate dot and dash curve **75**. I. e. a single radiator, with a screen, has a directivity pattern like the curve **75**. To determine the resultant field, the quadrature and in-phase component curves **71** and **73** are added together graphically and multiplied by the directivity factor curve **75**. The result of this operation is the solid line curve **77**, which represents the resultant field produced by the complete array with one position of the switch **49**. When the switch **49** is in its opposite position, the quadrature current component represented by the curve **71** is reversed, providing a resultant similar in shape to the resultant **77** but inverted with respect to the bearing axis. With the design illustrated in Fig. 1 the field pattern is 30° wide at the half energy point and the lobe displacement is 6° from the center line. It should be noted that the curves **71** and **73** are approximately tangent at their point of nearest approach, which occurs at an angle of about 45°. If the currents and phases of the radiator elements are so arranged that these curves do not cross, no spurious radiation lobes are produced.

The rotating capacitor **49** is part of a series resonant circuit which alternately grounds the junction points **29** and **44**. A short circuit at the junction point **29** reflects an open circuit at junction points **21** and **37** as a result of well known impedance inversion characteristics of quarter wave transmission lines. Similarly a short circuit at the junction point **44** reflects open circuits at points **23** and **37**. The inductance of the stub line **41** together with the capacitance between the condenser plates **46** and **55** is series resonant at the frequency of antenna operation. The rotor plate **55** is effectively grounded by means of the stub **57** which, together with the capacitance of the plates **51** and **55** is series resonant. The residual capacitances at the ungrounded points **29** and **44** are brought to parallel resonance by the stub lines **47** and **45** respectively so that these capacitances have no net effect on the normal transmission path through the ungrounded junction point. When the point **29** is grounded, current flows over the line sections **43** and **39**, so that the side group **5** leads the side group **3** in phase by an angle proportional to the length of the line section **25**. When the point **44** is grounded current flows over the path including sections **27** and **35** and the side group **3** leads. Thus the beam is displaced from left to right as the rotor of the capacitor **49** is turned. The rotor of the capacitor **49** is grounded through series resonance with the stub lines to avoid necessity for rotating ground connections which are difficult to achieve at high frequencies. This arrangement also prevents radio frequency currents from flowing down the motor shaft and through the motor bearings.

Thus the invention has been described as an antenna system for providing alternately overlapping directive radiation lobes. A relatively simple array is employed, comprising a central radiator group and two symmetrically disposed side groups. The central group is excited continuously and the side groups are excited out of phase with the central group, one side leading and the other side lagging by the same angle. The phase angles of the side groups are interchanged periodically to displace the radiation lobe from left to right. An improved switch is provided for this purpose, comprising a rotating capacitor provided with a single rotor and a plurality of stator plates. The rotor is grounded through a series resonant circuit including the capacitance to one of said stators.

We claim as our invention:

1. An antenna system for providing alternately overlapping directive pattern lobes, comprising a central radiator group and two side radiator

groups symmetrically disposed with respect thereto, each of said radiator groups comprising a pair of horizontal dipoles spaced ½ wave length apart vertically and electrically connected in parallel, said side groups being separated horizontally from said central group by ⅝ wave length, a main transmission line adapted to be connected to a utilization circuit, said transmission line being connected directly to said central radiator group and through branch circuits to said side radiator groups, a section of transmission line of a length equivalent to 50 electrical degrees and switching means arranged to alternately include said line section in the paths to said side radiator groups, said switching means comprising quarter wave length transmission line sections connected in series between said main line and each of said branch circuits, stub lines, and motor driven capacitor means connected to said quarter wave sections and to said stub lines, whereby said quarter wave sections are alternately short circuited through series resonant circuits including said capacitor means and said stub lines.

2. An antenna system for providing alternately overlapping directive pattern lobes, comprising a central radiator group and two side radiator groups symmetrically disposed with respect thereto, each of said radiator groups comprising a pair of horizontal dipoles spaced ½ wave length apart vertically and electrically connected in parallel, said side groups being separated horizontally from said central group by ⅝ wave length, means for constantly energizing said central group, means for energizing each of said side groups 25 degrees out of phase with said central group,

one leading, and one lagging, with currents in each side group radiator equal to one half the current in each center group radiator, and means for periodically reversing the phase relations of the energization of said side groups with respect to that of said central group.

3. The invention as set forth in claim 1, including a screen of conductive material disposed in a plane parallel to all of said radiator elements and spaced substantially ⅛ wave length therefrom.

4. A radio frequency distribution circuit including a main supply line, two branch lines, two transmission line sections ½ wave length long, each connecting one of said branch lines respectively to said main line, and a transmission line section of predetermined length connecting said half wave transmission line sections to each other, switching means arranged to alternately short circuit said half wave length sections at their midpoints, said switching means comprising cyclically variable capacitor means connected to said midpoints and stub lines connecting said variable capacitor means to ground, said stub lines being of such lengths that said stub lines, together with the maximum capacitance of said variable capacitor, comprise series resonant circuits.

5. The invention as set forth in claim 4 including inductive elements connected to said midpoints and so proportioned as to form circuits which are parallel resonant with the minimum capacitance of said variable capacitor at the frequency of operation of said system.

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