

Oct. 18, 1938.

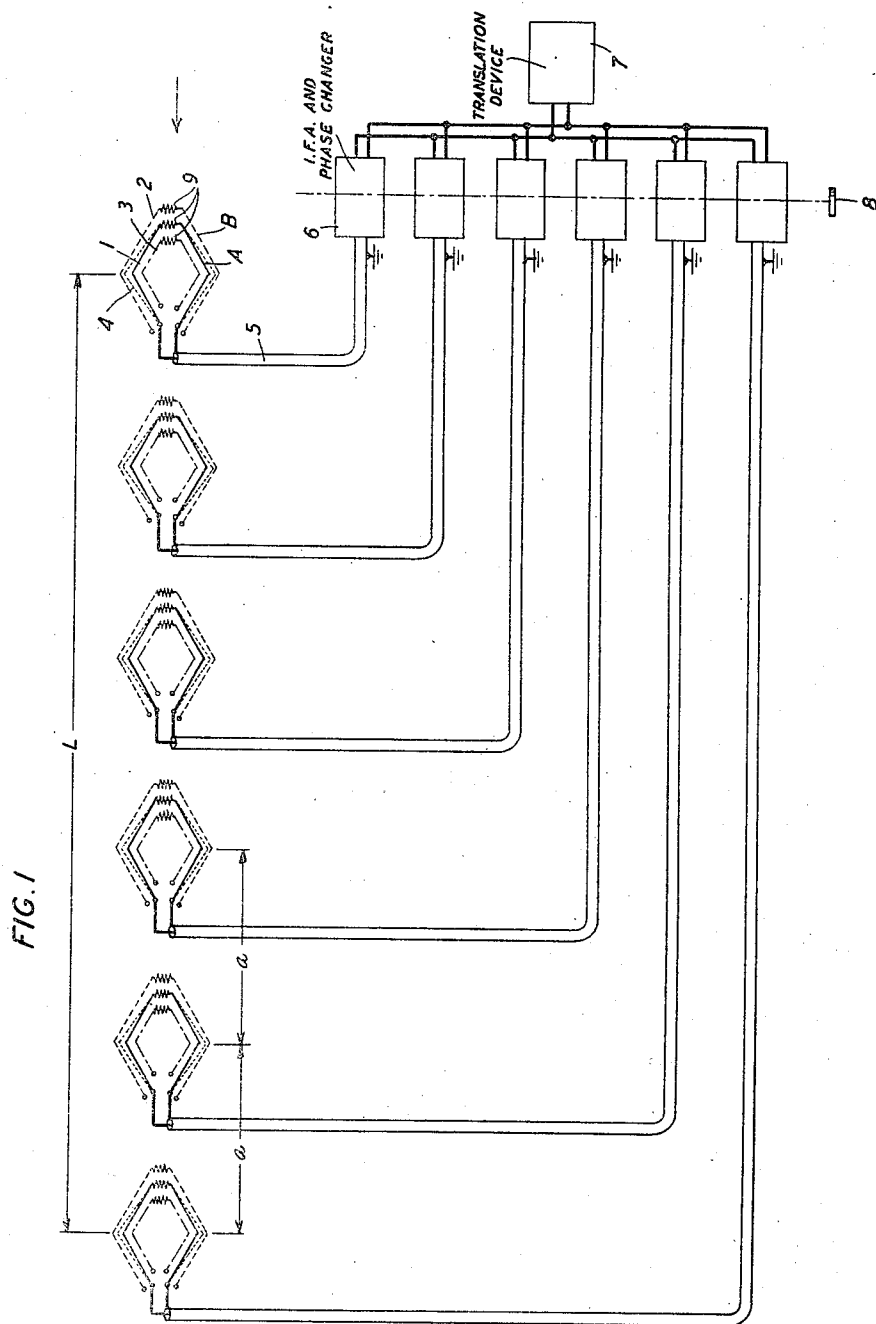
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2,133,806

RADIO COMMUNICATION SYSTEM

Filed June 5, 1936

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

FIG. 2 A

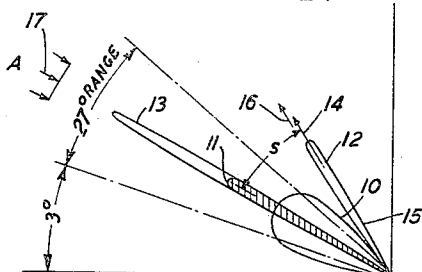


FIG. 2 B

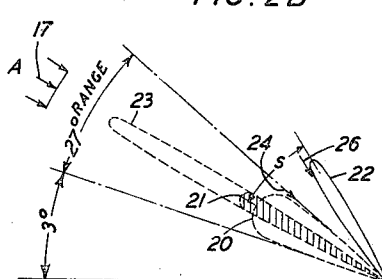


FIG. 2 C

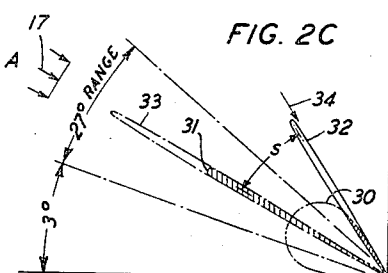


FIG. 3

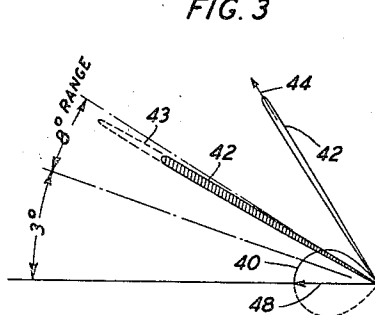
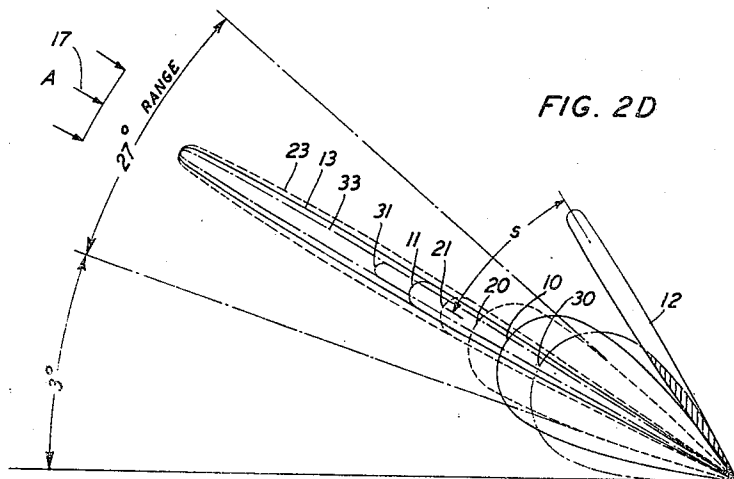


FIG. 2 D



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RADIO COMMUNICATION SYSTEM

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Application June 5, 1936, Serial No. 83,683

7 Claims. (Cl. 250—11)

This invention relates to radio communication systems and more particularly to a method and means for obtaining controllable and sharp directive transmission or reception in such systems.

5 In the recently issued Patent 2,041,600 granted to H. T. Friis, May 19, 1936, there is disclosed a method and system for eliminating fading, the system comprising a plurality of directive antenna units arranged in an array and connected through separate uni-controlled phase shifters to a translation device. The span or array length, the number of antenna units and the uniform spacing between units are chosen so that only one of several incoming waves from a distant 10 cooperating station is received when the maximum amplitude of the directive array cone and the maximum antenna directive lobe are aligned in a vertical plane with the desired wave by properly phasing the antenna currents. The antenna units may have any size provided the optimum unit spacing and phasing mentioned above are maintained and provided that the width of the unit directive lobe which, in general, is inversely related to the antenna size, is 15 greater than the normal operating or wave angle range and less than the angular spacing between the maximum array cone and the second or adjacent array major cone. It now appears desirable for economical and other reasons to employ in the method and system described above, antenna units of optimum size.

It is one object of this invention to obtain a sharp antenna directive characteristic.

It is another object of this invention to eliminate both general and selective fading in an economical and convenient manner.

It is still another object of this invention to vary or steer the maximum directive lobe of a receiving or transmitting antenna over a wider angular range than heretofore accomplished.

As already indicated, in the system and method disclosed in the above-mentioned patent to H. T. Friis the units are of similar type and size, the known normal angular wave direction range or cluster and the average angular spacing between wave directions in the cluster are critically related to and partly determine the array or span length, the number of similar size rhombic receiving antenna units and the spacing therebetween. According to one embodiment of this invention, the rhombic antenna units employed are critically dimensioned so as to produce or insure a directive maximum unit lobe sufficiently broad to include the angular range 55 of the cluster and of the adjustable lowest or

maximum array lobe, when the rhombic antenna directive null adjacent to and above the maximum unit lobe is aligned with the principal axis of the next maximum, usually the next lowest array lobe, or aligned with an array null adjacent to the next lowest major array lobe. In a different embodiment the principal axis of a rhombic lobe is aligned with a horizontal direction and a null is directed at the second major array or space factor lobe.

The invention will be more fully understood from the following description taken in connection with the drawings on which like reference characters designate elements of similar function and on which:

Fig. 1 represents an array which is similar to that disclosed in the patent to H. T. Friis and comprises units of optimum size or dimensions in accordance with the present invention.

Figs. 2A, 2B, 2C and 2D are directive diagrams useful in explaining the embodiment of the invention illustrated by Fig. 1; and

Fig. 3 illustrates a directive diagram of a different embodiment of the invention.

Referring to Fig. 1 reference numerals 1, 2 and 3 designate steerable rhombic antenna units of the type disclosed in my copending application Serial No. 685,340 filed August 16, 1933, the units being spaced a distance a in an array having a length L . Antennas 1, shown in full lines, have the optimum size or dimensions. Antennas 2, shown in dash lines, and antennas 3, shown in dash-dot lines, are larger and smaller, respectively, than the medium or optimum size and are shown for purpose of explanation. Any directive type of antenna may, of course, be employed instead of the rhombic antennas illustrated. Steering of the rhombic antenna lobe may be accomplished in several different ways. According to the method illustrated, the side apex angles are varied, whereby antenna 1 may assume the shape illustrated by the dotted lines 4. The antennas 1 are connected by means of coaxial lines 5 through separate intermediate frequency amplifiers and phase shifters 6 to the translation device 7, the phase shifters being uniformly graded in size and controlled by the single handle 8, as disclosed in the Friis patent. Reference numeral 9 designates an impedance for rendering the associated rhombic unit unidirective. Other means for rendering the rhombic antenna unidirective may, of course, be used instead of the terminating impedance. The arrow represents the desired vertical plane of wave propagation.

Fig. 2A illustrates the directive diagrams of a system employing the optimum size rhombic antennas 1, and Figs. 2B and 2C illustrate the directive diagrams of systems employing antennas 2 and 3, respectively. Fig. 2D illustrates the diagrams of Figs. 2A, 2B and 2C superimposed for ready comparison. In the above vertical plane diagrams each of reference numerals 10, 20 and 30 designates the typical or effective rhombic maximum directive lobe of the corresponding antenna. Numerals 11, 21 and 31 designate the maximum array or space factor cones, numerals 12, 22 and 32 designate the major array lobes adjacent the maximum array lobes, and numerals 13, 23 and 33 designate the overall or resultant system directive lobes or cones. The same range for the incoming wave cluster A (from 3 to 25 degrees), which shifts seasonally, and the same array lobe spacing S corresponding to a given unit spacing are assumed in the above diagrams.

Referring specifically to Figs. 1 and 2A, the side length of the rhombic antenna 1 is critically chosen so that the resulting antenna major lobe 10 includes all the wave directions in the cluster A when the rhombic directive null 14 is aligned with either the principal axis 15 of the second array lobe 12 or the array null 16 adjacent thereto. The lobe 10 and null 14 are accurately positioned by varying the interior rhombic angle, and for seasonal operation the null 14 may be positioned to coincide with axis 15 when maximum array lobe 11 is aligned with the center wave direction 17 of cluster A. In view of the relatively large width of unit lobe 10 the principal axis of the maximum array lobe 11 may, if desired, be aligned with a long minor axis of lobe 10, in order to receive the strongest wave, without material sacrifice in the directive gain of the system and without including waves of appreciable magnitude in the second major array lobe 12.

Referring now to Fig. 2B it will be seen that the sharp lobe 20 of the large expensive antenna 2 does not provide as wide an angular steering range for the maximum array lobe 21 as lobe 10, and does not include all the wave directions which are outside the normal range but included between the array lobes 11 and 12. An appreciable angular range is included between unit null 24 and the array null 26 adjacent lobe 22. Consequently frequent adjustment or steering of the unit lobe is required when the antennas are larger than the medium or optimum size. Referring to Fig. 2C, the broad lobe 30 of the small and inexpensive antenna 3, intersects two array lobes 31 and 32 and consequently permits undesired reception of more than the single wave, although it does provide a large steering range. The entire array lobe 32, it will be noted, is included between null 34 and the principal axis of lobe 30. The combined diagram of Fig. 2D fully illustrates in large scale the undesired effects resulting from the use of antennas having a size other than the optimum.

It is interesting to note, assuming it is desired to employ large antennas 2 and to render the length of the overall lobe 23 equal to that of lobe 13 of the optimum array, a shorter span and a fewer number of units should be employed as compared to the array containing optimum size units. This follows from the fact that the system or overall cone equals approximately the product of the array and unit characteristics. When the small antenna unit 3 is employed a longer span and a larger number of units are re-

quired, as compared to the optimum span, in order to render lobe 33 equal in length to lobe 13. Also, assuming a given unit spacing, the sharpness of the array lobes increases with an increase in the span length and the number of units.

Referring now to Fig. 3, the directive diagram of a system comprising small units is illustrated. The null 44 of the unit directive characteristic adjacent the large unit directive lobe 40 is aligned with the second array lobe 42 and the principal axis 48 of the unit lobe is aligned horizontally, whereby only one-half the unit lobe is actually utilized during operation. This arrangement provides a small steering range for the array cone 42, and overall lobe 43, but is advantageous from an economical standpoint in connection with systems in which the wave cluster is not large.

The characteristic or space factor for the array whose diagram is illustrated by Fig. 3 is given by the equation

$$K = \frac{\sin \frac{n}{2}[\theta - 2\pi a(1 - \cos \Delta)]}{\sin \frac{1}{2}[\theta - 2\pi a(1 - \cos \Delta)]} \quad (1)$$

where n =number of units
 a =unit spacing in wave-lengths
 θ =phase difference between currents in adjacent units
 Δ =elevation angle.

If we assume that the first or maximum and the second or major array lobes make, respectively, angles of 7 degrees and 16 degrees with the horizontal, the unit antenna size may be determined as follows.

The dominating phasing factor for the rhombic antenna, as given in my copending application mentioned above, may be written

$$F = \sin^2 \left[\frac{\pi l}{\lambda} (1 - \sin \phi \cos \Delta) \right] \quad (2)$$

where l =side length of rhombic antenna
 λ =mean wave-length of band
 ϕ =half of side apex angle
 Δ =elevation angle.

The first null is obtained when the bracketed term equals π and the first maximum is obtained when it equals

$$\frac{\pi}{2}$$

Consequently, by simultaneously solving the following equations

$$\frac{\pi l}{\lambda} (1 - \sin \phi \cos 16) = \pi \quad (3)$$

$$\frac{\pi l}{\lambda} (1 - \sin \phi \cos 0) = \frac{\pi}{2} \quad (4)$$

we can determine the optimum dimensions for an antenna whose maximum lobe is aligned with a horizontal direction and whose first null coincides with the undesired major array lobe.

Although the invention has been explained in connection with certain specific embodiments, it is to be understood that it is not to be limited to such embodiments. The invention is equally applicable to transmitting as well as receiving systems; and, as previously indicated, steerable and non-steerable directive antenna units other than the units illustrated may be employed within the scope of the invention.

What is claimed is:

1. A method of radio communication, utilizing a plurality of directive units arranged in an array and associated with a translation device,

and means for steering or changing the direction of maximum radiant action for each of said units and means for simultaneously steering the maximum and the adjacent major directions of action for the array, which comprises aligning the maximum direction of action for said array with the path of the strongest incoming wave, aligning a direction of action for each unit with said path and aligning a null direction of action for each unit with said major direction of action for said array.

2. A method of radio communication, utilizing a directionally steerable array having two vertical plane directive lobes and comprising a plurality of directive antenna units separately connected to a translation device, which comprises selecting antenna units each having a directive lobe equal in width to the angular distance between the horizontal array axis and the array lobe adjacent the lowest array lobe, including in the lowest array lobe the path or direction of only one of the several differently directed incoming or outgoing directions constituting a wave cluster, and positioning each unit directive lobe so as to embrace all and only the wave directions between the array lobe adjacent said lowest lobe and the array axis, whereby the cluster directions and the lowest array lobe are at all times included in the unit lobes regardless of movement of said cluster and a maximum steering range for the lowest array lobe is obtained.

3. A plurality of steerable directive antenna units arranged in an array and connected through separate phase shifters to a translation device, the directive characteristic of each unit including a maximum lobe and the directive characteristic of the array including in a vertical plane a low maximum lobe and a higher major lobe, the dimensions of the units each being such that the angular width of the unit directive lobe equals the angular distance between the horizontal plane and the principal axis of said array major lobe the maximum directive lobe of each unit being positioned so that it includes the normal wave angular range and the maximum array lobe and so that a null immediately adjacent said unit lobe coincides with an axis of a major array lobe adjacent to said maximum array lobe.

4. In combination, a plurality of antenna units arranged in an array and associated with a translation device, said units each having a vertical plane maximum directive lobe, the vertical plane directive characteristic of the array including a low maximum lobe and a higher major lobe, the dimensions of said units each being such that the angular width of the unit maximum lobe equals the angular distance between the horizontal plane and the principal axis of said array major lobe means for adjusting the directive characteristic of the array, the principal axis of the maximum array directive lobe and a minor axis of each maximum unit lobe being aligned with a desired wave direction, a unit null

immediately adjacent each of the maximum unit lobes being aligned with the principal axis of the array major lobe and the principal axis of each maximum unit lobe being aligned with a horizontal direction.

5. An antenna array having at least two vertical plane directive lobes and comprising a plurality of directive antenna units connected to a translation device, means for moving said lobes, each antenna unit having a maximum directive lobe equal in angular width to twice the angle between the longitudinal axis of the array and the second array lobe from the axis, and each unit having a directive null above the lobe, the unit lobe being positioned so that it includes the first array lobe and its principal axis coincides with the array axis and so that a unit null coincides with the principal axis of the second array lobe.

6. A directive antenna array having at least two vertical plane directive lobes and comprising a plurality of directive antenna units connected to a translation device, and having a directive lobe and a directive null, means for moving said lobes, the dimensions of each unit being critically chosen and such that each unit has a directive lobe equal in angular width to twice the angle included between the principal radius of the array lobe nearest the array axis and the array lobe adjacent said first-mentioned array lobe, said unit lobes each being superimposed on the first-mentioned array lobe and positioned so that the null aligns with the second-mentioned array lobe.

7. A method of obtaining a maximum steering range for a directive antenna array having in a vertical plane a low maximum lobe and a higher major lobe and comprising directive antenna units, each unit having a vertical plane directive lobe and a directive null immediately above the directive lobe, utilizing means for steering the array and unit lobes, which comprises selecting units each having a directive lobe equal in width in said plane to the angular distance between the horizontal plane and the array major lobe when the maximum array lobe is directed toward the center of an incoming wave cluster having a low arrival angle, aligning the said unit directive nulls with the said array major lobe when the maximum array lobe is directed as stated, and upon a material change in the cluster arrival angle again directing the maximum array lobe toward the cluster and aligning the unit directive nulls with the major array lobe, and maintaining regardless of changes in the cluster arrival angle the maximum array lobe aligned with the strongest incoming wave in said cluster, whereby at all times substantially each unit lobe includes the maximum array lobe and intercepts all the wave directions included in said vertical plane between the major array lobe and the horizontal plane.

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