

April 29, 1941.

E. BRUCE

2,239,775

RADIO COMMUNICATION

Filed March 2, 1939

FIG. 1

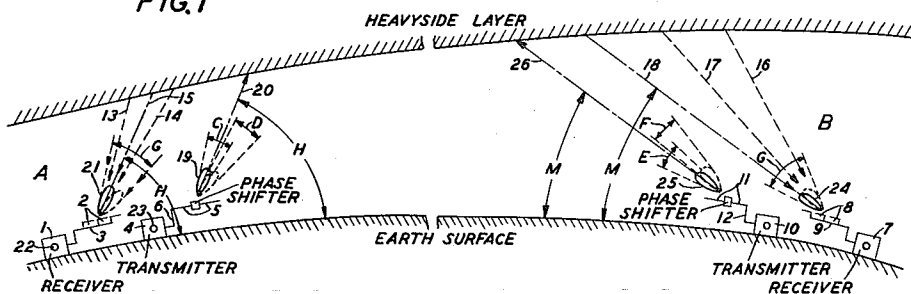


FIG. 2

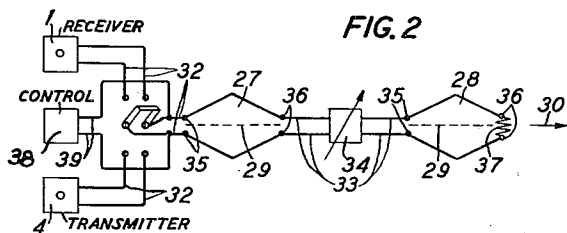


FIG. 3

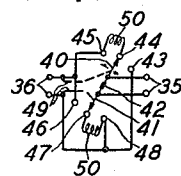


FIG 5

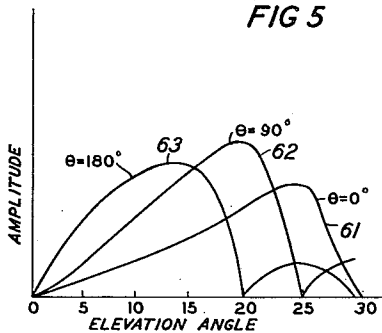
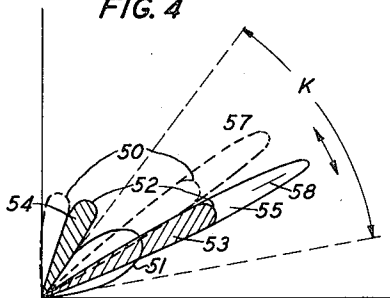


FIG. 4



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RADIO COMMUNICATION

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3 Claims. (Cl. 250—11)

This invention relates to a method of directive radio communication and to means for adjusting or moving the directive characteristic of an antenna system.

As is well known, radio waves emitted by a transmitting station travel over diverse paths of different lengths in reaching a receiving station and, at frequent periods, often oppose or annul each other at the receiving station and so produce fading. In order to secure optimum reception without fading it has heretofore been proposed to confine, by means of a steerable sharply directive antenna system, the communication to the single path followed by the strongest of the waves incoming at the receiving station. Since the path in the vertical plane of propagation of the most intense wave and also of the weaker waves changes frequently and sometimes rapidly, during the operating period, and within a somewhat well-defined angular range, it has been necessary to direct, at the transmitting station, the energy or wave along all paths within a range in the vertical plane corresponding to the above-mentioned receiving range, in order to insure proper energization at the receiving station of the optimum path, that is, the path of least attenuation within the range. Since the waves traveling along the unused paths are not utilized and represent lost energy, it appears desirable to concentrate or direct, at the transmitting station, a maximum amount of energy along whatever single path appears optimum at the receiving station and to redirect or reconcentrate the transmitted energy along a different path whenever it appears desirable or necessary in order to secure a maximum effect at the receiving point.

It is one object of this invention to improve two-way radio communication.

It is another object of this invention to establish a maximum incoming field at a receiving station.

It is still another object of this invention to maintain during the communication period and regardless of changes in the propagation direction of said field a maximum field at the receiving point.

It is a further object of this invention to cause a maximum amount of the transmitter output energy to follow the optimum path incoming at the receiving station regardless of directive changes in said path.

Applicant has discovered that the maximum effect is produced in a two-way long range communication system at the receiving system of

one station when the transmission from the transmitter of the distant cooperating station is directed along the path or direction corresponding to the optimum direction of reception, at the said cooperating station, of waves transmitted by the first-mentioned station. Therefore, in accordance with this invention, the communication between two cooperating stations is improved by ascertaining, as often as necessary, which of several paths incoming at one of the stations is followed by the wave of maximum intensity and simultaneously transmitting from said station a wave of maximum intensity in a direction corresponding with the ascertained path. More specifically, a receiving system and a transmitting system each comprising an antenna array, directly steerable in a given plane as, for example, the vertical plane, are utilized at one of the stations. The lobe or direction of maximum action of the receiving array is moved over the normal angular range in the aforementioned plane and the angle between the path or direction of the maximum incoming wave and a reference line or plane, such as the azimuth plane, and the longitudinal axis of the array is determined. Thereupon the lobe or direction of maximum action of the transmitting array is aligned with the ascertained direction. Whenever during the repeated excursions of the steerable receiving lobe a change in the direction or path of the maximum incoming wave is indicated, the transmitting lobe is repositioned so as to be aligned with the new path.

While any of the known highly directive and steerable antenna arrays, transmitting and receiving, may be utilized in practicing applicant's new method of communication, applicant has evolved in accordance with his invention, a simple and inexpensive steerable array which is particularly adapted for utilization in practicing his method. The steerable array embodying applicant's invention comprises at least two directive or non-directive units spaced in a linear array and connected in tandem with each other and through a single line to a transmission device such as a transmitter or a receiver. A variable phase shifter is included between the antenna units whereby the space factor directive characteristic of the array and the resultant system directive characteristic obtained by combining the unit antenna characteristic and the space factor characteristic, may be steered or positioned as desired.

The invention will be more fully understood from a perusal of the following specification

taken in conjunction with the drawing on which like reference characters designate elements of similar function and on which:

Fig. 1 illustrates applicant's method and apparatus suitable for practicing the method;

Fig. 2 illustrates in detail a directionally steerable antenna array which may be utilized in practicing the method;

Fig. 3 illustrates a phase shifter which may be used in the system of Fig. 2; and

Figs. 4 and 5 are directive diagrams useful in explaining the operation of the array of Fig. 2.

Referring to Fig. 1, reference characters A and B denote two cooperating stations remote from each other, as, for example, a European station and an American station, and each comprising a transmitting system and a receiving system. The receiving system at station A comprises a receiver 1, a directionally steerable antenna or antenna array 2, of any suitable type but preferably of the type disclosed in Patent 2,041,600, H. T. Friis, granted May 19, 1936, and a transmission line 3 connecting the receiver 1 to the array 2. The transmitting system at station A comprises a transmitter 4, a steerable antenna array 5 also of any suitable type but preferably of the type to be described in connection with Fig. 2, and a line 6 connecting the transmitter to the array 5. The receiving system at station B comprises a receiver 7, an antenna 8, and a line 9; and the transmitting system at this station comprises a transmitter 10, an antenna 11 and a line 12. The antennas 8 and 11 may each have a non-directive characteristic, a fixed directive characteristic or, as in the case of station A, a directionally steerable characteristic.

Radio waves, especially short waves propagated over long distances usually undergo one or more reflections from the Heaviside layer and the earth's surface and arrive at the receiving point over diverse paths having different directions such as those denoted by the reference numerals 13, 14 and 15 at station A or those designated by numerals 16, 17 and 18 at station B; and in general this is true even when the energy is emitted by a highly directive system which confines the transmission to a small angular range in the vertical plane as the range C or D at station A, or the range E or F at station B. The waves conveyed along the different paths vary in intensity and, as stated in my Patent 2,076,222, granted April 6, 1937, and in Patent 2,041,600 mentioned above, all waves except the maximum wave are preferably rejected by the receiving antenna system for the purpose of eliminating fading. Thus referring to Fig. 1, waves conducted along the ethereal paths 13 and 14 are rejected by the array 2 and only the maximum wave conducted along 15 is received and utilized. The angular range G of the incoming wave direction at station A or B varies and is to a large extent, especially under stabilized conditions in the ether transmitting medium, dependent upon the type, directive or non-directive, of transmitting antenna employed at the distant transmitting station and, if directive, upon the orientation or position of the transmitting directive characteristic or lobe. If the lobe 19 of the transmitting antenna at station A were pointed toward the zenith or in certain other directions included in the vertical great circle plane containing stations A and B, no energy would in all probability reach station A. On the other hand, when this lobe is pointed in the general direction of the distant receiving station B, waves of

different intensity ordinarily intercept station B. A wave of maximum intensity, however, is received at the distant receiving station B at any given period, applicant has found, only when the transmitting lobe at the cooperating station A is pointed so that its principal axis is aligned with the particular direction which coincides substantially with the optimum receiving direction at the aforementioned cooperating station A. Thus, if direction 15 represents the path at station A of the maximum incoming wave from station B, a maximum field is established at station B by the transmission from station A when a maximum amount of energy is transmitted from station A in the direction 20 which coincides with, or is parallel to, direction 15, substantially. Consequently, in practicing applicant's invention, the movable directive lobe 21 of the receiving antenna 2 at station A is steered, assuming a receiving system of the type disclosed in the Friis patent is utilized, by means of the unit control phase shifter dial and knob 22 through the normal range G of directions incoming from station B, for the purpose of ascertaining the direction followed by the wave of maximum intensity. The dial is preferably calibrated so as to indicate the elevation angle H of the optimum incoming wave direction. The receiver operator at station A then instructs the transmitter operator at station A to position the lobe 19 of the transmitting antenna 5 so as to have an elevation angle equal to H. The vertical plane direction or position of the principal axis of the lobe 19 is indicated by the dial 23. In a similar manner, assuming steerable antenna arrays are used at station B, the lobe 24 of the receiving antenna 8 is moved so as to be aligned with the direction of the strongest incoming wave direction as, for example, direction 18 which makes an angle M with the horizontal plane and the lobe 25 of the transmitting antenna 11 is adjusted so as to transmit in direction 26 which has an elevation angle M. The optimum angle of reception and transmission at station A may or may not agree with that at station B depending upon whether the Heaviside layer has a uniform height or, as illustrated, a non-uniform height and on other factors.

Referring to Fig. 2 reference numerals 27 and 28 designate horizontal rhombic antenna units of the type disclosed in my copending application Serial No. 513,063, filed February 3, 1931, the units being positioned so that their major or longitudinal diagonals 29 are colinear and aligned with a horizontal direction 30 extending in a vertical plane containing the distant cooperating station. The antenna units 27 and 28 are preferably structurally identical and are connected in series or tandem with each other. The array may be connected, by means of a switch 31 and transmission line comprising sections 32 and 33, to either a receiver 1 or a transmitter 4. A variable phase shifter 34 of any suitable type is included between the two antennas. More specifically, the device 1 or 4 is connected to the input or near-end terminals 35 of antenna 27 and the output or far-end terminals 36 of this antenna are connected through the line 33 and the adjustable phase shifter 34 to the input terminals 35 of antenna 28. A terminating impedance 37 is connected to the output terminals 36 of antenna 28. The phase shifter 34 is preferably remotely controlled by the device 38 at the receiver location, the low frequency or direct current energy for actuating the phase shifter being

supplied over line 39 and the radio frequency system comprising line 32, antenna 27 and line 33. The input impedance of antenna 28 is such as to render the antenna 27 unidirectional and the terminating impedance 27 has a value suitable for suppressing the back-fire radiation or reception. If desired, more than two units may be connected in tandem and to the device 31 by means of a single line; and the several phase shifters one of which is included between each pair of adjacent units may be remotely uncontrolled. In the case of large power installations separate arrays, such as illustrated by Fig. 2, may, of course, be permanently connected to the receiver and transmitter. The advantage of the switching arrangement which is useful for small power installations and is illustrated in Fig. 2, is that steering the lobe for receiving automatically positions the lobe properly for transmission.

While the phase shifter 34 may be arranged to produce any phase shift between 0 and 360 degrees, satisfactory operation may in certain instances be secured by utilizing in the system of Fig. 2 the simple inexpensive phase shifting device or arrangement illustrated by Fig. 3. Referring to Fig. 3, reference numbers 40 and 41 designate movable contacts which are separated by the insulating member 42 and which are arranged to move respectively over two sets of stationary contacts, one set comprising contacts 43, 44, 45 and the other set contacts 46, 47 and 48. The movable contacts are connected to the input terminals 35 of antenna 28 and are actuated preferably by energy supplied over the low frequency connections 49 shown by broken lines. A coil or line section 50 equal electrically to a quarter wave-length is connected between contacts 44 and 45 and a similar coil 50 is connected between contacts 47 and 48. The stationary contacts 43 and 48 are connected to one of the output terminals 36 of antenna 27 and the contacts 45 and 46 are connected to the other output terminal of antenna 27. It will thus be seen that a zero degree, a 90 degree or a 180 degree phase shift may be introduced between antennas 27 and 28 by proper actuation of the contacts 40 and 41.

Referring now to Figs. 4 and 5, the directive effect produced by changing the setting of the phase shifter 34 will be explained. Reference numeral 51 designates the vertical plane projection of the individual directive lobes of the rhombic antennas which lobe may for the purpose of this explanation be considered as being superimposed. Reference numeral 52 denotes a portion of the array or space factor vertical plane directive characteristic, the portion shown comprising the major lobe or cone 53 and the minor lobe or cone 54. As explained in the Friis patent, the over-all or resultant lobe 55 for the system is obtained by multiplying the unit antenna characteristic 51 and the array directive characteristic 52. Also, as explained in the Friis patent, the space factor characteristic and the resultant system characteristic may be steered over lobe 51 and moved, for example, to positions 56 and 57, respectively, by connecting the antenna units to the receiver or transmitter through separate lines and by changing the relative phase relation of the currents supplied to or delivered by the antennas 27 and 28. In applicant's system, Fig. 2, assuming an ordinary phase shifter is used, the phase relation of the antenna currents may similarly be altered a proper amount to secure align-

ment of the resultant lobe with any particular desired direction included in the range K.

If the special phase shifter illustrated by Fig. 3 is employed in the system of Fig. 2, the resultant characteristic may be aligned with any of three different directions within the range. In Fig. 5 the over-all characteristics obtained with zero, 90 and 180 degree phase difference are illustrated. Thus the principal axis 58 of the maximum over-all cone 55 is illustrated as having a 25 degree elevation angle for zero phase difference, a 20 degree elevation for 90 degree phase difference and a 15 degree angle for 180 degree phase difference. Since the angles 15, 20 and 25 degrees may be taken to represent respectively the normally low, mean and normally high angle of reception of horizontally polarized waves, the tandem array of Fig. 2 equipped with the inexpensive phase shifter illustrated by Fig. 3 may in practice be employed successfully and satisfactorily as the steerable transmitting system in practicing applicant's communication method described in connection with Fig. 1.

Although the invention has been described in connection with certain structures and apparatus, it is to be understood that it is not to be limited to the apparatus illustrated; and that other structures and devices may be utilized in successfully practicing the invention.

What is claimed is:

1. A method of communication between two radio stations utilizing at one of the stations only a single receiving system and a transmitting system each comprising a directionally steerable antenna, which comprises steering the maximum direction lobe of the receiving antenna over the normal range in a given plane of directions for incoming directions followed by a plurality of waves incoming from the other station, ascertaining the direction of the wave of greatest intensity, and aligning the maximum lobe of the transmitting antenna with the ascertained direction.

2. A method of communication between two radio stations utilizing at each station only a single receiving system and a transmitting system each comprising a directionally steerable antenna, which comprises steering at each station the maximum directive lobe of the receiving antenna over the normal range in a given plane of wave directions incoming from the other station, ascertaining the direction of the wave of greatest intensity and receiving energy from said wave, and aligning the maximum lobe of the transmitting antenna with the ascertained direction.

3. A method of communication between two stations utilizing at one of the stations only a single receiving system and a transmitting system each comprising an antenna having a relatively sharp maximum directive lobe in a given plane, and means for changing and indicating the position of said lobes in said plane, which comprises ascertaining the path of the strongest wave incoming from the other station, and aligning the lobes of the receiving and transmitting antennas with said path.

4. A method of communication between two stations utilizing at one station only a single receiving system and a transmitting system each comprising an antenna having a relatively sharp maximum directive lobe, means included in each system for moving the lobe in the great circle plane including the two stations, and means included in each system for indicating the angle

between the azimuth or horizontal plane and the principal axis of the lobe which comprises moving the lobe of the receiving antenna over the normal angular range in said plane of directions or paths traversed by waves incoming from the other station, observing the elevation angle of the path of the strongest incoming wave and aligning the principal axes of the receiving and transmitting antenna lobes with the said ascertained or observed path.

5. In a radio system, a directive array comprising a pair of spaced rhombic antenna units, a translation device, one antenna being connected through another of said antennas to the device, a variable phase shifter for moving the directive characteristic of said array included between said antennas and means including one of the antennas for remotely controlling the phase shifter.

6. In a radio system, a linear array comprising two spaced directive antenna units, said antennas being positioned so that the maximum lobes or cones of their individual directive characteristics are aligned with the same direction substantially, a translation device, said device being directly connected to one antenna and through said antenna to the other of said antennas, means for moving the array or space factor cone included between said antennas and means at said device for remotely controlling the last-mentioned means, whereby the resultant or combined lobe may be steered and aligned with a desired direction of wave propagation.

7. In a radio system, an array comprising a pair of spaced horizontal rhombic antenna units

having their longest diagonals colinearly oriented in a vertical plane of desired radiant action, a translation device connected to the input terminals of one unit and a terminating impedance connected to the output terminals of the other antenna units, an adjustable phase shifter connected between the output terminals of the first-mentioned unit and the input terminals of the other unit and means at said device and including the first-mentioned antenna unit for remotely controlling said phase shifter, whereby the maximum cone of the spaced factor characteristic of the array and the resultant directive lobe of the system may be aligned with a chosen path of transmission.

8. In a radio system, a pair of horizontal spaced rhombic antennas having their longitudinal or major axes aligned in a vertical plane including a distant cooperating station, substantially, and each having a pair of input and a pair of output terminals, a transmitter, a receiver, a single line for connecting said transmitter and receiver, alternatively, to the input terminals of the antenna positioned farthest from the cooperating station, a variable phase shifter connected between the output terminals of the said antenna and the input terminals of the other antenna comprising means for inserting a zero phase shift, a 90 degree phase shift, or a 180 degree phase shift, means including the first-mentioned antenna for controlling the phase shifter and a terminating impedance connected to the output terminals of the last-mentioned antenna.

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