

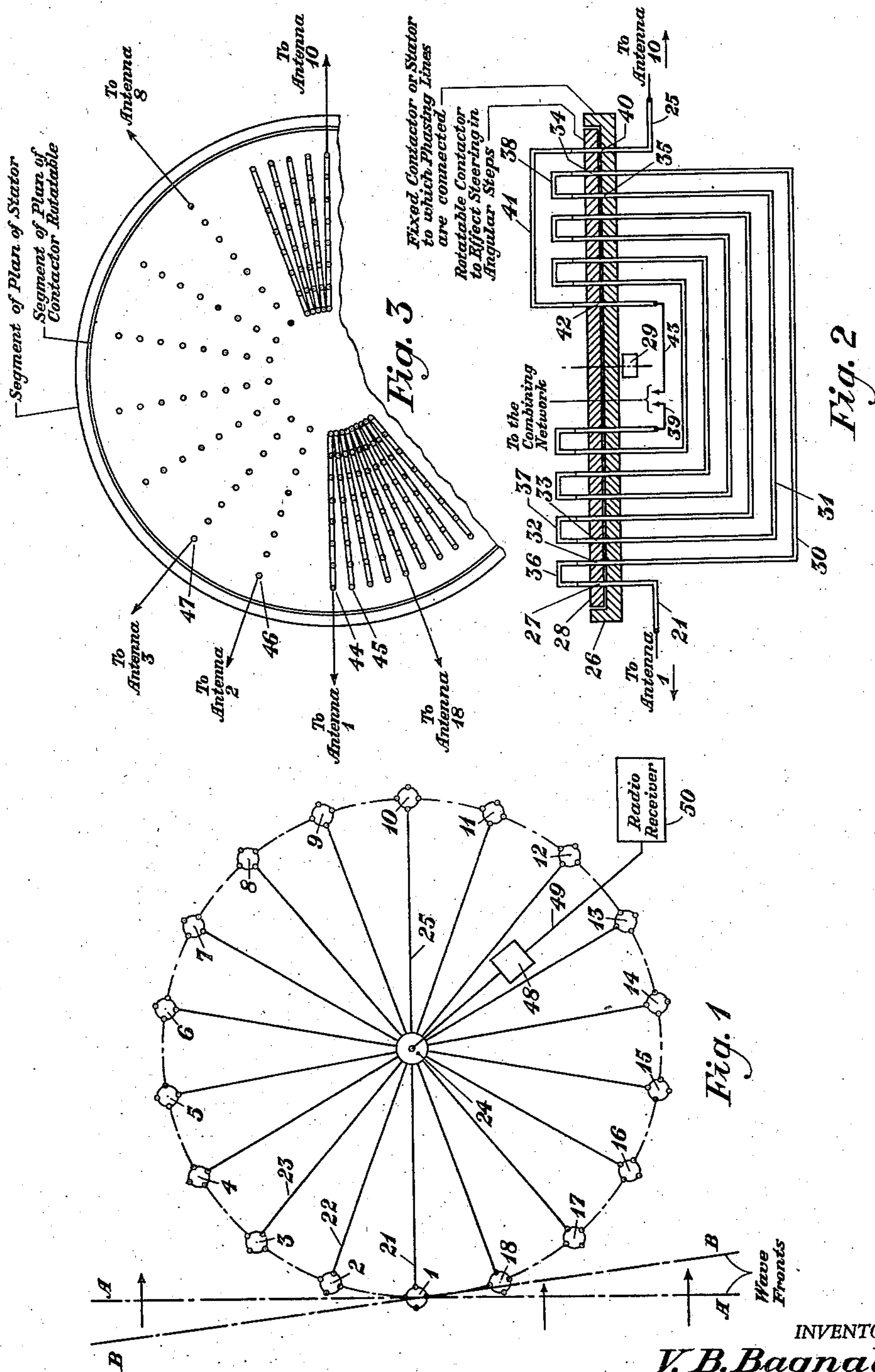
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DIRECTIONAL RADIO SYSTEM

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DIRECTIONAL RADIO SYSTEM

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This invention relates to a directional radio system for transmitting and receiving signals, and particularly to one in which a symmetrical antenna array may be steered effectively either in steps or continuously to obtain maximum directivity in any horizontal direction, and, which is also capable of effecting an adjustment of the vertical directive pattern.

In my copending application Serial No. 542,536, filed June 28, 1944, is described an invention by which the directional characteristic of a radio receiving or transmitting system, involving an antenna array, may, after being adjusted for maximum reception from or transmission in a given direction, be altered at will to afford maximum reception from or transmission in any other direction throughout 360 degrees horizontally. In the arrangements of the invention shown in the said application the voltage waves of reception or transmission are brought into phase for their maximum cumulative effect by means of phase shifters which are mounted upon a rotatable drum or disc so that their relative positions are not altered by changes in the angular positions of the drum or disc. The phase shifters therein shown are artificial networks, but mention was also made of the applicability of coaxial transmission lines of suitable length to effect the necessary phase shift in the voltage waves from or to the several antennas of the array. As is pointed out hereinafter, the amount of coaxial line required for the phasing of a practical antenna installation would be so large as to render impracticable the rotation of such coaxial line upon a drum or disc in the manner in which the artificial phase shifting networks are rotated.

The present invention resides in means employing coaxial transmission lines to shift the phase of the voltage waves in order to effect maximum reception or transmission in a given direction, the said means being so arranged that substantially the entire amount of coaxial line remains in fixed position throughout the rotation of the switching means by which the connections to the several antennas are changed to effect a change in the directional pattern of the array for maximum effect in a desired direction.

This invention will be clearly understood from the following description when read in connection with the attached drawing in which Figure 1 is a plan view of an antenna array illustrating the principle of the present invention and Figs. 2 and 3 show rotatable means applicable to the array of Fig. 1 to effect the steering of the array, as desired to conform to a changed direction of reception and transmission, Fig. 2 being a vertical cross-sectional view of the rotatable arrangement, the plan view of which is shown in Fig. 3.

The array shown in Figure 1 comprises eight-

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een vertical antennas herein illustrated as being of the cage type each connected by an individual coaxial transmission line such as 21, 22, 23, to phasing and steering apparatus 24 located at the center of the array. In the arrangements described in my aforementioned copending application the phasing apparatus consisted of an electrical network suitably designed and adjusted to provide the necessary phase shift of the currents in the lines with which the apparatus was connected. Mention was also made therein of the use of lengths of coaxial cable in connection with the transmission lines extending to the several antennas to provide the necessary phase shift. Such coaxial phasing lines of the proper lengths could be provided at the several points and the currents from the several antennas, when adjusted as to phase by traversing those coaxial lines would then be combined and impressed upon a common output circuit extending to a translating device such as a radio receiver. Such an arrangement would require the mounting of the phasing line on a rotatable disc or turn-table of some sort with sliding connections to each transmission line. The total amount of coaxial line required for phasing is approximately equal to the product of the radius of the array circle and the number of antennas thereon. Thus, for an array of eighteen elements, as shown in Fig. 1, on a circle 250 feet in diameter (a practicable size for ship-to-shore services operated in the 4—8—13—17 megacycle bands) about 4500 feet of coaxial phasing line would be required. Obviously, a steering arrangement requiring the rotation of such a large mass of coaxial cable would probably be objectionable in a commercial operating system. By means of the arrangement shown in Figs. 2 and 3 is is practicable to obtain the desired phasing and steering of the array by means in which the coaxial lines, used in phasing, remain fixed, and the difficulties inherent in the rotation of such a large mass of such coaxial lines is avoided. Furthermore, the arrangement shown in those figures makes it possible to control the steering, both horizontally and vertically, in steps as small as desired without increasing the total amount of phasing line beyond the minimum hereinbefore stated.

The possibility of obtaining the proper phasing of the currents for smaller steps than are represented by the total number of antennas, without increasing the total amount of phasing line, depends upon the basic principle that the sum of the lengths of phasing lines required for the diametrically opposite antennas is constant (independent of the vertical or horizontal angle to which the array is steered) and is approximately equal to the diameter of the circular array. Fig. 2 shows the manner in which the length of coaxial line, employed in phasing the received currents,

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is connected into the circuits in which flow the currents that are to be phased. The coaxial line 21 extends to the antenna 1 and the coaxial line 25 of the antenna 10. Those antennas are oppositely disposed upon the circumference of the circle upon which all of the antennas are located, and the transmission lines 21 and 25 are equal in length. The lines 21 and 25 extend to the stator 26 of a phasing arrangement and terminate at the points 27 and 40, respectively in sliding coaxial jacks which, being well known, need not be described in detail. The conductors of the line 21 are connected through the contacts of the jack at point 27 with patching conductors supported by the rotatable disc 28 which may be mounted in any suitable way and rotated by means of a motor 29 operated preferably by remote control from the plate where the radio receiver is located. The length of coaxial cable employed for phasing the received currents of each pair of oppositely disposed antennas is sectionalized and the sections, such as 30 and 31, are terminated also upon sliding jacks at the points 32, 33 and also at the points 34 and 35. By means of patching links, represented by the inverted U-shaped sections 36 and 37, the connections may be made between the incoming lines such as 21, and the various sections of the phasing lines such as 30 and 31. In the arrangement shown in Fig. 2, all of the sections of the entire length of the phasing line have been connected in series, as may be seen by tracing the connection through from the line 21, the patching link 36 to the section 30 which, at the opposite side of the disc, is connected by the patching link 38 to the section 31 of the phasing line and that, in turn, is connected by the link 37 to the next succeeding section of the phasing line. The inner end 39 of that phasing line is then connected through a combining network to the radio receiver. The oppositely disposed antenna 10 is connected by the line 25 to the jack at the point 40 where the connection is continued through the link 41 to the point 42, thence through another jack to the conductor 43 that also extends through the combining network to the radio receiver.

The manner in which that device functions is as follows: if voltages were set up in antennas 1 and 10 simultaneously, the resultant currents would be in phase at the combining point at the center of the array since the transmission lines 21 and 25 are similar and of equal length. Assuming, however, that the wave front A—A of the radio waves is traveling in the direction represented by the arrows, as indicated in Fig. 1, the current resulting from the voltage set up in antenna 1 will be in advance of the current resulting from the voltage set up in antenna 10. In order to provide the necessary phase adjustment to bring those currents in phase, so as to produce an additive effect upon the radio receiver, the necessary lag in the current from antenna 1 is effected by the introduction of the required number of coaxial line sections, such as 30 and 31 of Fig. 2. Assuming that the entire number of sections are essential for such phase adjustment, the various lines would be linked together by patching lines such as 36, 37, 38, etc., as shown in Fig. 2, and the current from antenna 1 after traversing the line 21 would pass back and forth over the sections 30, 31, etc., and would finally pass from conductor 39 to the combining network 48 shown on Fig. 1. Simultaneously, the current transmitted over conductor 25 to the arrangement shown in Fig. 2 would pass merely through the patching link 41 (without any intervening coaxial

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sections) to conductor 43 and would then be impressed upon network 48.

The transmission lines from each of the other pairs of oppositely disposed antennas would terminate upon sliding coaxial jacks in the stator of the phasing arrangement at positions represented by 46 and 47 upon Fig. 3, and would there be connected by patching links similar to those shown in Fig. 2 to a sectionalized length of coaxial line similar to that shown in the latter figure. That is to say, the antenna 2 would be connected by its transmission line 22 at the point 46, shown on Fig. 3, to a sectionalized coaxial network similar to that shown in Fig. 2. And likewise, the oppositely disposed antenna 11, which forms a doublet with respect to antenna 2 would be connected by its transmission line to a sliding jack upon the stator in the manner in which the transmission line 25 is connected at the point 40 as shown in Fig. 2. Since the difference in phase of the currents from antennas 2 and 11 will not be the same as the difference in phase of the currents from antennas 1 and 10, the connections of the transmission lines from the antennas 2 and 11 to the sections of the phasing lines, as shown in Fig. 2, would be different from the connections shown in the latter figure. That is to say, the transmission line 22 from antenna 2 would be connected by patching links similar to 36, 37, etc., to the number of sections of phasing lines necessary to produce the phase adjustment between the currents from antennas 2 and 11 at the instant of time those currents are impressed upon network 48 which is connected by the line 49 to the radio receiver.

It will thus be seen that although it is essential to have for each pair of oppositely disposed antennas the same total length of phasing line that is required for each of the other pairs of oppositely disposed antennas, such a large mass of coaxial lines does not have to be rotated but remains fixed in position; the only rotatable parts are the patching links which extend to the sliding coaxial jacks and effect the connection between the various sections of the total length of the phasing lines.

Fig. 3 shows also, in fragmentary form, means by which the steering of the antenna array may be effected by steps that are smaller than the angular separation between the adjacent antennas, which, in the arrangement shown in Fig. 1, amounts to 20 degrees. If the wave front takes the position represented by B—B, which is tangent to the circle of the array at a point intermediate the antennas 1 and 18, the phase of the currents set up in the several antennas would be different from that resulting from waves having the wave front A—A, and that difference of the angle of approach represented by the wave front B—B would require a different adjustment of the phasing apparatus. This is done by providing other sliding coaxial jacks and the necessary patching links upon the rotatable disc in the manner represented by the circles between the parallel lines indicated by 45. These circles represent contact points similar to 27, 32, 33, etc., of Fig. 2. Other patching links, performing the same function as 36 and 37 of Fig. 2, would be provided to connect in series with the line 21 the required number of sections of phasing lines to effect the proper phase adjustment in the current resulting from the voltage set up in antenna 1 when the wave front has the position B—B which adjustment would obviously be different from that necessary to effect phase adjustment when the

wave front had the position A—A. By providing a number of such intermediate contact points by which different patching arrangements may be effected for different angles of approach of the wave front of the radio waves, it is possible to steer the antenna array so as to provide directivity in a greater number of directions than that represented by the number of antennas employed in the array. This is important because for a circular array the sharpness of the directivity characteristic increases both with the number of antenna elements and the diameter of the array relative to the operating wave length. To obtain high gain and also signal-to-noise improvement, it is desirable to use a large number of antennas and have the diameter of the array large compared to the operating wave length. To minimize inter-action between elements, it is desirable to have the diameter of the array large compared with the number of elements. For an antenna of the circular type having a relatively high gain and a correspondingly sharp directional characteristic, it is desirable to have the steering in steps small enough to enable the antenna to be steered to its approximate maximum in any direction. That result is obtained by means of the arrangements shown in the figures of the drawing in which this invention is embodied.

Although this invention has been described in connection with its function to receive radio waves for subsequent impression upon a radio receiver, it is to be understood that such description is purely illustrative of the structure and the mode of functioning of the invention, but does not constitute a limitation upon it since it is equally applicable for use in connection with a radio transmitter. The sole change necessary to effect such a difference in functioning would be merely an interchange of the connections of the apparatus to provide for the difference in direction of travel of the currents between the antenna elements and the translating device, that is, a radio receiver or radio transmitter.

While this invention has been disclosed as embodied in particular forms and arrangements of parts, it is not so limited since it is capable of embodiment in other and different forms without departing from the spirit and scope of the appended claims.

What is claimed is:

1. In a directional radio system, the directivity of which may be altered at will, the combination with a circular antenna array comprising a plurality of antennas of a radio receiver effectively connected to all of said antennas, and phase adjusting means interposed in such connection to adjust the phase of the voltage waves received from said antennas, the said phase adjusting means comprising a plurality of sectionalized lengths of transmission lines each length being adapted for connection to one of a pair of oppositely located antennas of the said circular array, and a rotatable switching device adapted to automatically adjust the phase of the said voltage waves from each pair of antennas by connecting the required number of sections to effect the phase shift from each such pair of antennas as to produce an additive effect of the voltage waves from all of said antennas upon the said receiver.

2. In a directional radio system the directivity of which may be altered at will, the combination with a circular antenna array comprising an even number of antennas arranged in pairs, of means

effectively connected to all of said antennas to combine the voltage waves set up in the said antennas, and means interposed in the said connection between each pair of antennas and the combining means to bring into phase the voltage waves set up in each pair of oppositely disposed antennas, the phase controlling means for each pair comprising a sectionalized length of coaxial line and means to insert in the said connection between each pair of antennas and the combining means the necessary number of sections of coaxial line to provide the time-shift in the voltage waves from the pair of oppositely disposed antennas to which a given length of coaxial line may be connected, in order to bring the said waves into phase.

3. In a directional radio system the combination with an antenna array comprising a plurality of antennas arranged symmetrically about a central point, means to apply current to each of the said antennas, the said means comprising a plurality of sections of coaxial transmission lines each proportioned to control the phase and amplitude of the currents in a pair of oppositely disposed antennas whereby the directional characteristic may be controlled, and means to alter at will the said characteristic by simultaneously changing the connections of the said means to the said antennas, in accordance with a fixed plan.

4. In a directional radio system, the directivity of which may be altered at will, the combination with a circular antenna array comprising an even number of antennas arranged in pairs, the antennas of which are oppositely disposed upon the circumference of the circle, and means to bring into the same phase the voltage waves from each pair of oppositely disposed antennas, the phase controlling means comprising a plurality of sections of coaxial line and means to connect in series with one of the antennas of a pair the number of sections of coaxial cable to provide the time shift necessary to bring into phase the voltage waves from the pair of oppositely disposed antennas.

5. In a directional radio system, the directivity of which may be altered at will, the combination with a circular antenna array comprising an even number of antennas arranged in pairs, of means effectively connected to all of said antennas to combine the voltage waves set up in the said antennas, and a section of coaxial transmission line interposed in the said connection between each pair of antennas and the combining means to bring into phase the voltage waves set up in each pair of oppositely disposed antennas.

6. The invention defined by claim 5 further characterized by means rotatable at will to effect the connection of the said sections of coaxial line to other pairs of antennas than those to which they were previously connected whereby the directional pattern of the said array may be shifted.

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