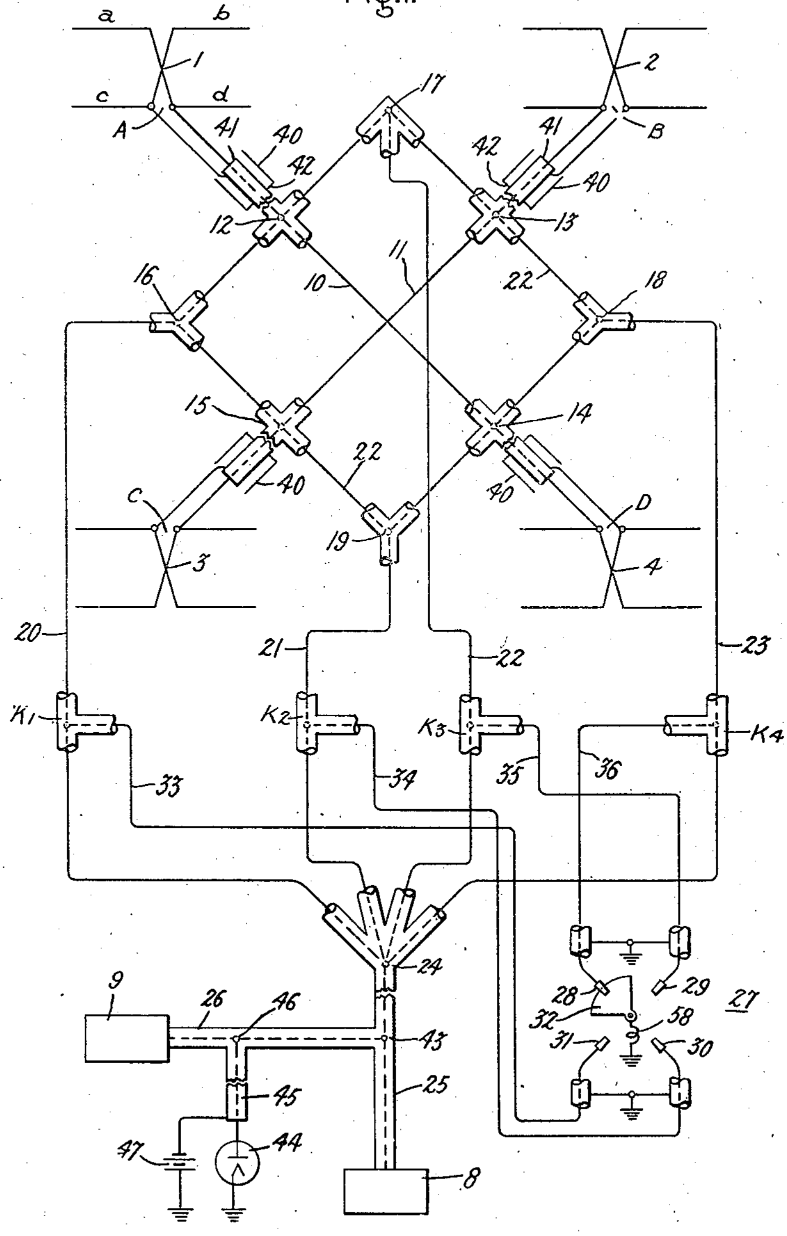
Dec. 3, 1946. F. G. PATTERSON 2,412,161

TRANSMISSION SYSTEM

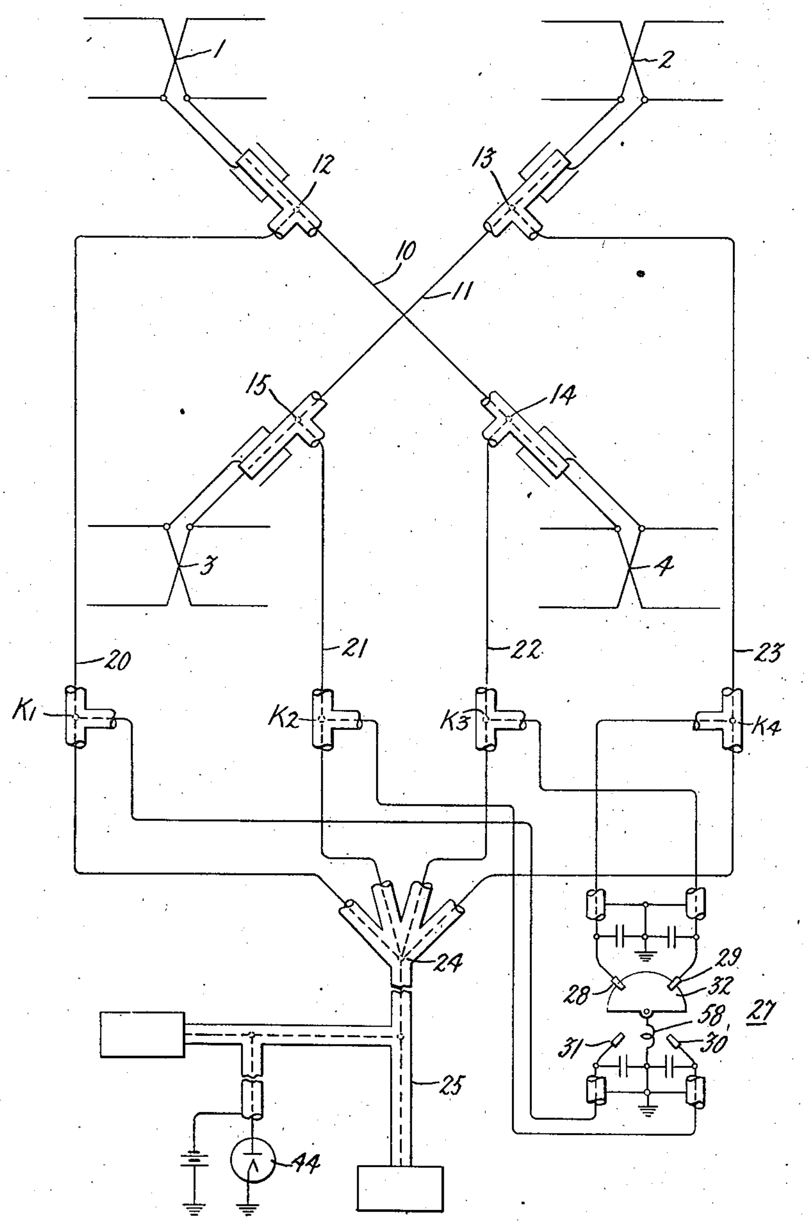
Filed Dec. 1, 1941 3 Sheets-Sheet 1

Fig. 1.



Inventor:
Franklin G. Patterson,
by Harry E. Dunham
His Attorney.

Fig. 2.



Inventor:
Franklin G. Patterson,
by Harry E. Dunham
His Attorney.

Dec. 3, 1946. F. G. PATTERSON 2,412,161

TRANSMISSION SYSTEM

Filed Dec. 1, 1941 3 Sheets-Sheet 3

Fig. 6.

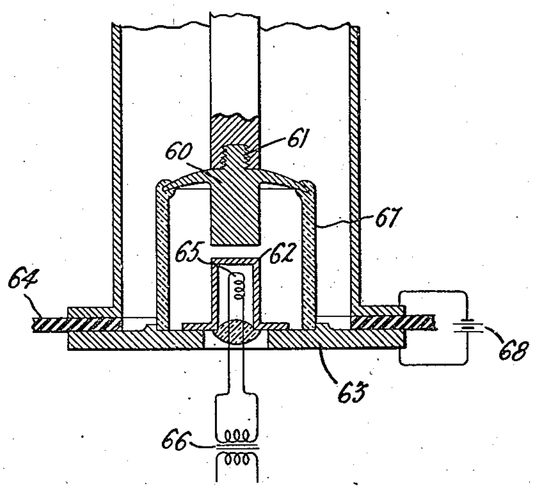


Fig. 4.

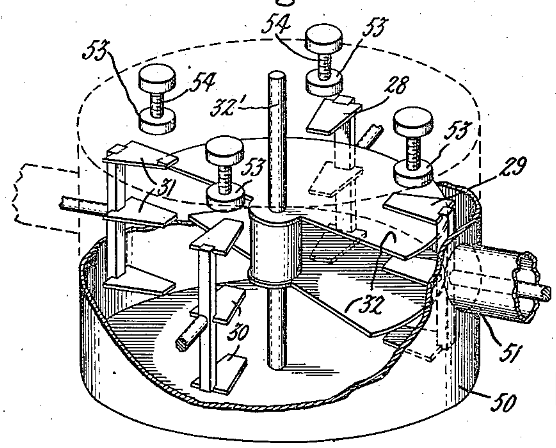


Fig. 3.

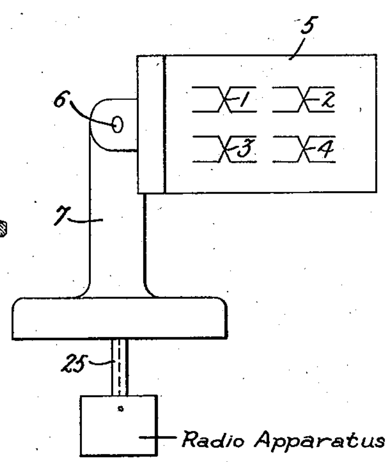
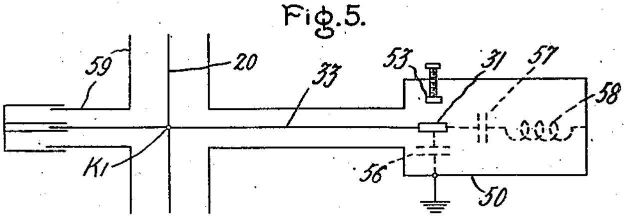


Fig. 5.



Inventor:
Franklin G. Patterson,
by Harry E. Dunham
His Attorney.

Patented Dec. 3, 1946

2,412,161

UNITED STATES PATENT OFFICE

2,412,161

TRANSMISSION SYSTEM

Franklin G. Patterson, Schenectady, N. Y., assignor to General Electric Company, a corporation of New York

Application December 1, 1941, Serial No. 421,126

19 Claims. (Cl. 250—11)

1

My invention relates to high frequency transmission systems, such as may be employed, for example, in equipment for directive radio purposes.

In copending application Serial No. 410,836, filed September 15, 1941, by Lawrence M. Leeds and entitled Directive radio system, and which is assigned to the same assignee as my present application, is disclosed a directive radio system in which the direction with respect to which the system has maximum effect may be varied about the normal of the antenna array employed by changing the transmission line through which transmission occurs between the different elements of the array and the associated transmitter or receiver.

One of the objects of my present invention is to provide improved means whereby this result is effected.

Another object of my invention is to provide such means in which when energy is being transmitted over any line between the apparatus and the antennae array the transmission efficiency of that line is not materially impaired by any line connected thereto over which no useful transmission of energy occurs.

Another object of my invention is to improve and simplify such equipments, to effect certain economies therein, and to increase the facility of construction of such systems to afford impedance matching throughout.

Still another object of my invention relates to the switching means whereby the change in lines over which transmission occurs is brought about. An object of my invention is to improve such system and to render its operation more satisfactory.

My invention has for another of its objects to provide improved means whereby switching in high frequency circuits, in general, may be effected.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings in which Fig. 1 represents an embodiment of my invention; Fig. 2 represents a modification thereof; Fig. 3 represents a mattress on which the antennae of Figs. 1 and 2 may be mounted; Fig. 4 represents a condenser switching device of the type employed in the form of the

2

invention shown in Fig. 2; Fig. 5 represents a modification, and Fig. 6 represents a diode employed in the invention.

Referring to Fig. 1 of the drawings, I have represented at 1, 2, 3 and 4 four antenna elements which may be mounted in a mattress at the corners of a rectangle. Each of these elements comprises four dipoles *a*, *b*, *c* and *d*, the dipoles *a* and *b* being arranged end to end, the dipoles *c* and *d* being arranged end to end, and the dipoles *c* and *d* being positioned one half wave length from the dipoles *a* and *b* and parallel thereto. The end of dipole *a* adjacent dipole *b* is connected to the end of dipole *d*, which is adjacent the end of dipole *c*, and similarly the ends of dipoles *c* and *b* are connected together.

Energy is supplied to each radiating element for transmission, and is received therefrom during reception, at certain feed terminals A, B, C and D for the respective antenna elements.

The positioning of the different antenna elements with respect to each other is better illustrated in Fig. 3 where they are shown arranged in the form of a rectangle, the different antenna elements 3 and 4 being positioned a half wave length from the elements 1 and 2 and the elements 2 and 4 being positioned end to end with respect to the elements 1 and 3 respectively.

These various radiators may be arranged in a mattress 5 as shown in Fig. 3, in front of reflectors if desired, and energized through transmission lines which extend to a common point on the mattress and then through a common line down through the pedestal 7 to the radio apparatus, which may comprise a transmitter and receiver. This transmission line is indicated at 25 in Fig. 3 and the radio apparatus is designated on the drawings by that legend. So arranged the system is arranged to project a beam of radio waves in a direction at right angles to the plane of the mattress and to receive radio waves with maximum intensity from that direction. In accordance with the equipment presently to be disclosed, however, this beam may be projected upwardly or downwardly from the normal or either to the right or left. This may be effected electrically and without alteration of any structure mounted on the mattress 5 itself.

The mattress 5 is arranged for rotation about a horizontal pivot 6 whereby it may be rotated in a vertical plane for orientation of the direction of maximum effect of the mattress in the vertical plane. The pivot 6 is mounted in a support 7, which may be arranged for rotation in the horizontal plane thereby to orient the direction of maximum effect of the mattress in the horizontal plane.

Returning now to Fig. 1, it will be observed that the antenna elements are shown as separated with respect to each other for the purpose of clearness of the drawings.

This antenna system comprising the elements 1, 2, 3 and 4 is arranged to be energized from a transmitter 8 shown at the bottom of the drawings during transmission, and during reception is arranged to supply received waves to a receiver 9. The connections from the various antenna elements to this transmitter and receiver are made through concentric transmission lines comprising an inner conductor and an outer sheath which is grounded throughout its length. For the purpose of clearness in the drawings, this sheath is shown only fragmentarily on the drawings.

This transmission line system comprises a concentric transmission line 10 extending from the feed point A of antenna 1 to the feed point D of antenna 4, and a second transmission line 11 extendig from feed point B of antenna element 2 to feed point C of antenna element 3. From points 12, 13, 14 and 15 on these lines, transmission lines also extend to points 16, 17, 18 and 19. Additional transmission lines 20, 21, 22 and 23 extend, respectively, from these latter points 16, 17, 18 and 19 to a common point 24, which may be on the mattress, and then over the common transmission line 25 to the transmitter 8 and over a branch 26 to the receiver 9. Of course, both the transmitter and receiver may be arranged at a fixed point.

The points 12 and 14 are each equidistant from the midpoint of the line 10, and similarly, the points 13 and 15 are equidistant from the midpoint of the line 11. Also point 17 is equidistant from the points 12 and 13, point 18 equidistant from the points 13 and 14, point 19 equidistant from the points 15 and 14, and point 16 is equidistant from the points 12 and 15.

During transmission or reception energy is transmitted or received, as the case may be, at any time through but one of the transmission lines 20, 21, 22, 23, the remaining three lines being disabled. In this way the directivity of the antenna system may be varied; that is, the directivity of the system is dependent upon the line 20, 21, 22 or 23 over which the connection is made between the various antennae and the radio apparatus.

The mechanism for selecting the different lines 20, 21, 22 and 23 comprises an impedance switching device 27 which may be mounted on the mattress 5 of Fig. 3 and which may have four stationary capacitance electrodes 28, 29, 30 and 31 and also a rotatable electrode 32, which is arranged to cooperate in succession with the various electrodes 28, 29, 30 and 31. Each of these stationary electrodes 28, 29, 30 and 31 is connected through one of the standing wave transmission lines 33, 34, 35, 36 to a corresponding K point, designated K1, K2, K3 and K4, on one of the lines 20, 21, 22 and 23. These stub lines 33, 34, 35 and 36 each have a length something less than a quarter of a wave length of the wave at which the system operates, or of such a length plus a half wave length, or integral multiple thereof. Preferably these lines are in the neighborhood of an eighth of a wave length in length. The capacitance between the fixed electrodes 29, 30 and 31, which are not in cooperation with the rotating electrode 32, is adjusted as by means of trimmer electrodes, not shown, to a value such that the corresponding line 33, 34 or 35 acts at its respective K point upon the associated transmission line 20, 21 or 22 as though it had a length equal to a quarter of a wave length of a wave having the frequency at which the system operates. Thus, these lines 33, 34 and 35, with the electrode 32 in the position shown, act as effective short circuits at the points K1, K2 and K3 on the lines 20, 21 and 22. Therefore, lines 20, 21 and 22 are incapable of transmission of energy between the antenna system and the radio apparatus 8 or 9.

The line 23, however, is in condition for transmission since electrode 32 is in cooperating relation with the electrode 28, which is connected through transmission line 36 to the point K4 on line 23. The impedance within the device 27, with electrode 32 in the position shown, is of such value that this line acts at the point K4 as though it had a length equal to a half a wave length of the wave at which the system operates and thus it amounts to an open circuit at that point. Thus the transmission of energy may readily be effected along line 23 past the point K4.

The impedance within device 27 between the stationary electrode and shield for this latter mode of operation, is inductive, the inductance being that present in the path through the rotor to ground, as will later be more particularly explained. This inductance is conventionally represented in Figs. 1 and 2 at 58.

It is necessary, however, that the short circuits which appear at points K1, K2 and K3 be not effective at the point 24 and for this reason the distance from line 24 to any K point along any of the lines 20, 21, 22 and 23 is equal to a quarter of a wave length, or odd multiple thereof. Of course, a transmission line having a length of a quarter of a wave length, or odd multiple thereof, acts an an impedance inversion network; that is, if the impedance appearing at one end thereof is lower than the surge impedance of the line, a correspondingly higher impedance appears at the other end. Thus the short circuit which appears at K1, K2 and K3, with switch 27 in the position shown, acts as an open circuit at the point 24.

Energy transmitted over line 23 must reach the elements 1, 2, 3 and 4 in proper phase to produce a corresponding shift of the direction of the beam and hence, in accordance with my invention, it is confined to transmission lines of such length as to produce the required phase relations. To this end the lines 20, 21, 22 and 23 all have a length equal to a half of a wave length of the wave at which the system operates or a multiple thereof. Such a line produces the same impedance at one end that it has at the other. Thus the short circuits which are produced at the K points K1, K2 and K3 appear at the points 16, 17 and 19. These points 16, 17, 18 and 19 are connected to lines 10 and 11 through intermediate line sections, 16, 12; 16, 15; 17, 12; 17, 13; etc., which are of a quarter of a wave length in length or an odd multiple thereof. Thus the short circuit at the points 16, 17 and 19 appear as open circuits at the points of connection to the lines 10 and 11. Thus energy supplied from the transmitter over the line 23 to the point 18 reaches the line 11 at point 13 and is then transmitted in both directions to the antennae 3 and 2. Similarly it is transmitted from the point 18 to the point 14 on line 10 and thence over the line 10 in both directions to the antenna elements 1 and 4. The distance from the point 18 over line 11 to the antenna 3 is greater than to the antenna 2 and thus the voltage applied to antenna 3 is delayed in phase with respect to that applied to antenna 2, and similarly voltage applied to antenna 1 is delayed in phase with respect to that applied to antenna 4. The resultant phase relations produce a shift of the beam to a direction at an angle to the normal of the mattress in the horizontal plane. During reception waves arriving from the same direction upon the various elements arrive at the point 18 in phase and are thus transmitted over the line 23 to the receiver.

Now if the rotating electrode 32 be rotated through 90° to cooperate with electrode 29, then transmission takes place over line 22 and is prevented over lines 20, 21 and 23. Such energy passes from the point 17 to the point 12 and thence over line 10 to the antennae 1 and 4, and it passes from the point 17 to the point 13 over the line 11 to the antennae 2 and 3. The phase relations resulting from the difference in lengths of the lines produce a tilt of the beam from the normal in the vertical plane.

The connections are symmetrical with respect to all of the lines 20, 21, 22 and 23 and thus, as the rotor 32 moves about in a clockwise direction and cooperates in succession with the various electrodes 28, 29, 30 and 31, the beam is projected first to the right of the normal in the horizontal plane, then above the normal in the vertical plane, then to the left of the normal in the horizontal, and then below the normal in the vertical plane, or vice versa, as the case may be.

The extent of the tilt of the beam from the normal of the array is, of course, determined by the length of lines 10 and 11 between respective feed points 12 and 14, and 13 and 15, and these lengths may be varied as desired.

Since all of the transmission lines have the outer shield conductor thereof grounded in any suitable way and since the impedance between the terminals A, B, C and D at any of the antennae is balanced with respect to ground by reason of the form of the antennae employed, it is necessary that means be employed on each transmission line to match the balanced impedance of the respective antennae with the unbalanced impedance of the respective line. For this season the end of each line extending from the points 12, 13, 14 and 15 is provided with a sleeve 40 having a length equal to a quarter of a wave length of the wave at which the system operates and which is grounded to the sheath of the transmission line and neighboring structure but which is insulated from the last quarter wave length 41 of the sheath of the transmission line about which it is mounted. This sleeve 40, since it is connected to the sheath at the point 42, acts with the end 41 of the sheath as a quarter wave length transmission line short circuited at the point 42. Thus the end 41 oscillates with respect to ground in opposed phase relation to the oscillations which appear on the inner conductor at the corresponding point and thus an impedance balanced with respect to ground appears between the inner conductor and the sheath 41 at the end of the line. This impedance may be connected through open wire lines to the terminals A, B, C and D respectively.

The transmitter 8 presents a low impedance to the transmission line 25. In order that this low impedance may not impair reception, the line 25 has a length equal to an odd multiple of a quarter wave length, or multiple thereof, between the transmitter 8 and the point 43 to which the receiver is connected.

Equipment of the type to which my invention may be applied may be adapted for the transmission of impulses in rapid succession and for reception thereof as by reason of reflection from remote objects during intervals between the transmitted impulses. The transmitted impulses are, of course, very intense and must not be permitted to reach the receiver with their full intensity because if they did, impulses of such intensity would be likely to render the receiver insensitive and its sensitivity might not be recovered in time to effect the desired reception. In fact, the intense transmitted impulses may permanently injure the receiver. To avoid such effects the diode 44 is provided, this diode having its anode connected to the inner conductor of a stub transmission line 45 extending to a point 46 on the transmission line 26. Its cathode is grounded and connected to the sheath of the conductor through a source of potential 47. During transmission the high potential on the inner conductor of the transmission line causes the diode 44 to become conductive and of low impedance. The stub line 45 is of a half wave length in length and thus the low impedance of diode 44 appears at the point 46 and protects this receiver from the transmitted impulse. This point 46, however, is at a distance equal to a quarter of a wave length from the point 43 so that the low impedance at the point 46 appears as an open circuit at the point 43 and thus does not impair transmission.

The system as thus described possesses an advantage with respect to the matching of impedances throughout the network. Thus, for example, let us assume that the lines 10 and 11 have a surge impedance equal to 4Z. With the capacitance electrode in the position shown, transmission takes places as previously described over line 23 to the point 18 and thence to lines 10 and 11 at the points 14 and 13 respectively. If the line 10 has an impedance of 4Z, the line leading from 18 to 14 may be made to have an impedance 2Z since the portions of line 10 extending in opposite directions from point 14 are in parallel and thus have a parallel impedance amounting to 2Z. Perfect match of impedances thus appears at the point 14.

The same is true with respect to the point 13, the line from the point 18 to the point 13 having an impedance equal to 2Z.

For the same reason the line 23 has an impedance equal to Z since its impedance is a match to the parallel impedance of the lines extending from the point 18 to the points 13 and 14.

This same proportion of impedances, of course, exists throughout the network. All of lines 20, 21, 22, 23, 25, 26, 33, 34, 35 and 36 may be of the same impedance and of the same construction.

Fig. 2 represents a modification of my invention in which the lines 20, 21, 22 and 23 are connected directly to points 12, 15, 14 and 13 respectively, these points being spaced on lines 10 and 11 as previously described. The switching device 27 in this case differs from that shown in Fig. 1 only in that the rotating electrode 32 is in the shape of a semi-circle, or half of a disk, so that it cooperates at any one time with two of the stationary electrodes 28, 29, 30 and 31. Thus with the electrode 32 in the position shown on the drawings, short circuits are produced at the points K1 and K2 and open circuits at the points K3 and K4. Energy is then transmitted simultaneously over the lines 22 and 23 and thence over the lines 10 and 11 to the different antennae elements thereby to produce a titling of the beam in the horizontal plane.

If condenser electrode 32 be rotated clockwise through 90°, then transmission takes place over lines 21 and 22 and the beam is tilted in the vertical plane. If it be rotated through 180°, transmission takes place over lines 20 and 21 and the beam is titled in the horizontal plane opposite to that previously described and, similarly, if it be rotated through 270°, transmission takes place over lines 20 and 23 and the beam is rotated in the vertical plane in the opposite direction from that previously mentioned.

This system provides some simplification over that previously described and offers some of the advantages with respect to the matching of impedances. Thus, if the lines 10 and 11 have an impedance of 4Z, the portion of lines 20, 21, 22 and 23 above the respective K points should have an impedance equal to 2Z. That portion below the respective K point, however, must be proportioned to produce at the point 24 such an impedance that two lines extending from point 24 to respective K points thereon match the impedance of the line 25 at the point 24.

This form of my invention is more particularly claimed in copending application Serial No. 412,-452, filed September 26, 1941, by Richard C. Longfellow, and which is assigned to the same assignee as my present application.

Fig. 4 shows the capacitance switching device comprising the four stationary electrodes 28, 29, 30 and 31. These electrodes are housed within a chamber 50 which may be grounded and connected securely to the sheath of each of the different transmission lines as indicated at 51.

Of course, each of the different electrodes 28, 29, 30 and 31 has capacitance with respect to the sheath whether or not the rotating electrode 32 be in position to cooperate therewith. This capacitance may be adjustable as by means of additional electrodes 53 suitably mounted as, for example, upon screw-threaded adjustment members extending through the wall of the housing 50 whereby the distance between such electrodes and the respective electrodes 28, 29, 30, 31 may be varied. The capacitance of the electrode 31, for example, may be adjusted when the electrode 32 is removed from cooperating relation therewith, by adjustment of the respective screw-threaded member 54, to such a value that this capacity resonates the associated transmission line to produce an impedance at the opposite end thereof approximating that of a transmission having a length equal to a quarter of a wave length and which is open at its far end. When rotor 32 is brought into cooperating relation with the electrode 31, then the impedance resonates to produce impedance at its opposite end approximating the impedance of a line having a length equal to a half of a wave length and open at its far end. This result is secured in the initial design of the apparatus by proper proportioning of the area and spacing of the plates of the rotor and stator and by proper proportioning of the length of the path from electrodes 32 through the shaft on which they are mounted, and through the housing 50, back to the sheath of the transmission line in question.

If the lines leading to the impedance device 27 be less than any odd multiple (of course including the multiple 1) of a quarter of a wave length by less than a quarter of a wave length, then the impedance across the line to produce the quarter-wave mode of operation must be capacitive. A proper value of capacity may readily be secured by adjustment of the trimmer electrodes, such as those indicated at 53, to increase or decrease the capacity between the stator electrode and the shield of the line.

Assuming lines of the same length, the impedance across the line to produce the half wave mode of action must be inductive. The inductance present is that inherent in the path from the stationary electrode, through the rotor electrode, the shaft on which the rotor electrode is mounted and thence through the housing 50 back to the shield of the line in question. By proper design of this path including the spacing of the rotor plates with respect to the stator plates, by proper choice of the area of these plates, and, particularly by proper choice of the length of the shaft 32′ in which most of the inductance lies, the impedance between the stator electrode and the shield of the line may be made inductive when the rotor electrode meshes with the stator electrode. This inductive reactance may be made of such a value that the impedance looking into the line at its opposite end is substantially that of a half wave length line open at its far end. Moreover, this inductive reactance may be secured without disturbing the adjustment required to produce the capacitive reactance necessary to produce the quarter-wave mode of operation.

Of course, if the lines leading to the impedance device were of length less than an even multiple of a quarter wave length by less than one quarter of a wave length, the same operation may be secured but in that case the inductive reactance is necessary to produce the open quarter-wave mode of action and the capacitive reactance is necessary to produce the open half-wave mode of action. This adjustment of the apparatus may be employed in the arrangement of Fig. 2 quite as well as that previously described. In the arrangement of Fig. 1 it is necessary that lines leading to the impedance device 27 be of length less than an odd multiple, including one, of a quarter of a wave length by less than a quarter of a wave length.

As thus described, the system resonates rather sharply at the two modes of operation and if the frequency at which the system operates is changed to any considerable extent, it is necessary that readjustment be made for operation at the new frequency. The capacitance adjustment for operation at the quarter-wave mode is readily secured by adjustment of the trimmer electrodes 53. Since the inductive reactance necessary to secure the half-wave mode of operation lies largely in the rotor and in the shaft on which it is mounted, it is not so readily adjustable. It is therefore desirable that additional means be provided to secure high impedance at the K points in the half-wave mode of operation at any frequency substantially different from that for which the equipment was designed. One form of such additional means is shown in Fig. 5.

In Fig. 5, I have shown conductors 20 and 33 of Fig. 1 joined at the point K1. Conductor 33 extends to the electrode 31 of the capacitance device 50. In this capacitance device, the capacitance between the eletrode 31 and ground, when the rotor is removed from electrode 27, is represented by the dotted lines at 56. This capacity may be adjusted, as by trimmer electrodes 53, to produce the quarter-wave mode of operation.

The further component of the impedance between electrode 31 and ground, when the rotor meshes with this electrode, is represented as comprising the series combination of capacitance 57 and inductance 58 in parallel with capacitance 56. These impedances may be proportioned, as previously described, to produce inductive reactance between electrode 31 and ground for the half-wave mode of operation at the frequency for which the device is designed. If it be desired to change the frequency at which the system operates to any considerable extent, a stub line 59 connected to point K1 and of adjustable length to effect the required impedance may be employed. The adjustment of length may be secured by telescoping inner and outer conductors as conventionally represented on the drawings. The length of this stub line may be adjusted to cause it to resonate with any reactance presented by line 33 at point K1 to produce very high impedance between point K1 and ground. That is, capacitance 56 may now be adjusted as before to produce a short circuit between the inner and outer conductors at point K1 when the rotor is in its most remote position from electrode 31. In the event that the inductance of the path 57, 58 be not such that sufficiently high impedance is produced at the point K1 when the rotor enmeshes with the stator electrode 31, then line 59 may be adjusted in length to produce very high impedance between the inner and outer conductors at point 55.

Fig. 6 shows the diode, which is indicated at 44 in Figs. 1 and 2. This diode comprises an anode 60 having a screw-threaded projection 61 from the top thereof which may be screwed into the end of the inner conductor of the associated transmission line. It also has a cathode 62 which may be mounted upon a conducting plate 63, which closes the end of the transmission line, but which is insulated therefrom by means of insulation 64. This cathode may be heated by means of a heater 65 energized through a transformer 66. The space between the anode 60 and cathode 62 is enclosed by means of a glass cylinder 67 hermetically sealed both to the anode 60 and to the plate 63.

The battery 68 may be connected between the plate 63 and the sheath of the respective transmission line and thence through any apparatus which may be connected to the transmission line to the anode 60. This battery is poled to render the anode negative with respect to the cathode thereby to prevent flow of electrons to the anode during normal conditions in the absence of signals on the inner conductor. This avoids noise effect by reason of thermal agitation and the like.

While I have shown particular embodiments of my invention, it will, of course, be understood that I do not wish to be limited thereto since various modifications may be made both in the circuit arrangements and instrumentalities employed without departing from the spirit and scope of my invention, and I contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination, a radio apparatus, a plurality of antenna elements arranged in an array, a plurality of transmission lines extending from said apparatus in said antenna elements, and interconnections between said antenna elements whereby energy may be transmitted between said apparatus and all of said antenna elements over any one of said lines, and means to disable all of said lines except the one over which said transmission occurs and to cause all of said interconnections which are unused during transmission over any one line to present high impedance to that line at the point of interconnection therewith.

2. In combination, a radio apparatus, a plurality of antenna elements arranged in an array, a plurality of transmission lines extending between said apparatus and said antenna elements, interconnections between said elements whereby energy may be transmitted over any one of said transmission lines between said apparatus and all of the antennae of said array, said interconnections being positioned and proportioned to cause said antennae to operate in different relative phase relations dependent upon the line over which transmission occurs, means selectively to disable all of said lines except that one over which transmission occurs and to produce high impedance at the point of interconnection of any disabled line with any line over which transmission occurs.

3. In combination, a radio apparatus, a plurality of antenna elements arranged in an array, a plurality of transmission lines extending from said array to a common point and thence to said apparatus, interconnections between said lines and said antenna elements whereby energy may be transmitted between all of said antenna elements and said apparatus over any one of said lines, said interconnections being positioned and proportioned to cause said antenna elements to operate in different relative phase relations dependent upon and varying with the line over which transmission occurs, and means selectively to disable all of said lines except that one over which transmission occurs and to produce high impedance across said one line at said common point and at the point of any of said interconnections with said line.

4. In combination, a radio apparatus, a plurality of antenna elements arranged at the vertices of a polygon, antenna elements at diagonally opposite vertices of said polygon being connected together through respective interconnections, a plurality of transmission lines extending to said apparatus, each of said lines being connected through respective matching line sections to a point on each of said interconnections, each of said points being unequally spaced from the respective antenna elements interconnected by the respective interconnections, said transmission lines having equal surge impedance, and each of said transmission lines having surge impedance equal to a quarter of the surge impedance of said interconnections to which they are connected and to one-half of the surge impedance of the respective matching line sections.

5. In combination, a radio apparatus, a plurality of antenna elements arranged at the vertices of a polygon, antenna elements at diagonally opposite vertices of said polygon being connected together through respective interconnections, a plurality of transmission lines extending to said apparatus, each of said lines being connected through intermediate line sections to points on each of said interconnections unequally spaced from the respective antenna elements, and means to produce low impedance across any of said lines at a point removed from said intermediate line sections by a distance such that said low impedance is presented to said sections and said sections having such length that they simultaneously

present high impedance to the respective interconnections.

6. In combination, a radio apparatus, a plurality of antenna elements arranged in an array, a plurality of transmission lines extending from said apparatus in said antenna elements, and interconnections between said antenna elements whereby energy may be transmitted between said apparatus and all of said antenna elements over any one of said lines, and means to disable all lines except the one over which said transmission occurs and to cause all of said interconnections which are unused during transmission over any one line to present high impedance to that line at the point of interconnection therewith, said means comprising means simultaneously to produce high impedance across any one of said lines at a point thereon and low impedance across all of the other lines at a corresponding point thereon, said points being positioned on the respective line at a distance from the interconnection to which the respective line is connected that said low impedance at said point produces high impedance at said interconnection.

7. In combination, a plurality of antenna elements arranged at the corners of a rectangle, elements at diagonally opposite corners of said rectangle being connected together, the interconnections forming a phasing cross, radio apparatus, a plurality of transmission lines, each of said lines extending from said apparatus to an arm of the cross, and switching means selectively to disable certain of said lines thereby to confine transmission between said antennae and said apparatus to paths of lengths selected by said switching means thereby to vary the relative phase relations between said antenna elements.

8. In combination, an antenna array comprising a plurality of antenna elements arranged at the corners of a rectangle, and having a direction of maximum effect variable about the normal of said array in accord with the phase relations of voltages on the different elements, connections between said antenna elements positioned at diagonally opposite corners of said rectangle forming a phasing cross, radio apparatus, a plurality of transmission lines, each of said lines extending from said apparatus to an arm of said cross, and means selectively to disable certain of said lines thereby to confine transmission to paths between said antenna elements and said apparatus in accordance with the direction in which maximum effect of said array is desired.

9. In combination, a radio apparatus, a plurality of antenna elements arranged in an array, a plurality of transmission lines extending from said apparatus in said antenna elements, and interconnections between said antenna elements whereby energy may be transmitted between said apparatus and all of said antenna elements over any one of said lines, switching means comprising standing wave line sections extending from a point on each of said transmission lines and having a length different from any integral multiple, including one, of a quarter of a wave length of the wave transmitted over said lines, and means to produce across the end of any of said standing wave lines such an impedance that it disables the respective transmission line and simultaneously to produce across another of said standing wave lines such an impedance that it presents high impedance to the respective transmission line.

10. In combination, a transmission system having a plurality of branches from a common point, means to interrupt transmission of power over certain of said branches while maintaining transmission over another branch, said means comprising a plurality of stub lines, one stub line projecting from each of said branches at a point distant from said common point of said line by a distance equal to an odd multiple of a quarter of a wave length of the wave to be transmitted, and said stub lines having lengths different from any multiple of a quarter of said wave length, and an impedance device arranged to vary the impedance across the end of each stub line between two values, one value being such as to cause the respective stub line to act on the respective branch as though it were open circuited at its far end and its length were a quarter of a wave length thereby to impede transmission past said stub line, and the other value being such as to cause the respective stub line to act on the respective branch as though it were open circuited at its far end and had a length equal to a half wave length, said impedance device causing one stub to act as a quarter wave length line when another acts as a half wave length line.

11. In combination, a high frequency apparatus, a plurality of transmission lines extending therefrom over which energy is to be transmitted alterately, an impedance switching device connected through a stub line to each of said lines at a point distant from said source by a quarter of a wave length, or multiple thereof, of the wave to be transmitted, and each of said stub lines having a length different from a quarter of said wave length or any multiple thereof, said impedance device presenting impedance across the end of each stub line varying between two values, one of said values causing the respective stub line to present low impedance to the corresponding transmission line and the other value causing said stub line to present high impedance to said transmission line, and said impedance device presenting a value of impedance to one stub line causing it to present high impedance to the respective transmission line when another stub line presents low impedance to its respective transmission line.

12. In combination, high frequency apparatus, a plurality of transmission lines extending therefrom over which energy is to be transmitted alternately, an impedance device having a plurality of stationary capacitance electrodes, each electrode being connected to a respective one of said lines, and having a movable electrode arranged to cooperate with said stationary electrodes in succession, the conductor connecting each electrode to its respective line having a length different from a quarter of a wave length or any multiple thereof, of the wave to be transmitted over the respective line.

13. In combination, a standing wave transmission line having a length different from any integral multiple of a quarter of a wave length of the wave at which said line operates, an impedance connected across one end thereof, and means to vary said impedance between two values, one of said values producing, by reason of the distributed properties of said line, a low impedance at the other end thereof, and the other value producing at the other end of the line, by reason of the distributed properties of said line, a high impedance.

14. In combination, a short wave transmission line, means to control transmission of energy through said line, said means comprising an im-

pedance device connected across said line through a stub line having a length different from any multiple of a quarter of the wave length of the wave transmitted through said short wave line, the impedance of said device being variable between two values, one of said values being such as to cause said stub line to appear as an open circuited quarter wave length line across said first line, and the other of said values being such as to cause said stub line to appear as an open circuited half wave length line across said first line.

15. In combination, a transmission line having a length different from a quarter of a wave length, or any integral multiple thereof, of the wave at which it operates, said line having an impedance device connected across one end thereof, said impedance device comprising a stator electrode connected to one side of said line and a rotor electrode connected to the other side of said line, said rotor electrode being movable to and from proximity to said stator electrode, and when in proximity to said stator electrode producing high impedance at the opposite end of said line, and the capacitance between said stator electrode and the other side of said line where said rotor is removed from said stator being such as to produce low impedance at the opposite end of said line.

16. In combination, a transmission line having a length different from a quarter of a wave length, or any integral multiple thereof, of the wave at which said line operates, one conductor of said line terminating in a stationary capacitance electrode, a capacitance electrode mounted for rotation about a shaft and cooperating in one position in its rotation with said stationary electrode, said shaft being connected to the other side of said line, the impedance between said stationary electrode and said other side of said line being capacitive when said rotor electrode is removed therefrom and such as to produce low impedance at the opposite end of the line, and the impedance between said stationary electrode and said other side of said line being inductive when said rotating electrode cooperates with said stationary electrode and such as to produce high impedance at the opposite end of said line.

17. In combination, a standing wave transmission line having a length different from a quarter of a wave length of the wave at which it operates, and an impedance device connected across one end thereof, said impedance device, in one condition thereof, having inductive reactance, and in another condition thereof, having capacitive reactance, the values of said reactances being such that the impedance at the other end of said line by reason of the distributed properties of said line is changed from a high value to a low value upon change from one of said conditions to the other.

18. An impedance device having a stationary capacitance electrode and a movable capacitance electrode cooperating therewith, a standing wave impedance utilization line connected between said movable and stationary electrodes, the impedance presented to said line by said impedance device when said movable electrode is nearest said stationary electrode being inductive and such that the impedance looking into said line from its opposite end is that of a line having a length equal to an integral multiple of a quarter of a wave length, and the impedance presented to said line when said movable electrode is removed from said stationary electrode being capacitive and such that the impedance looking into said line at its opposite end is that of a line having length different from said first mentioned length by a quarter of a wave length.

19. An impedance device having impedance variable between two values, a standing wave impedance utilization line connected thereto, one of said values being inductive and such that the impedance looking into said line at its opposite end is that of a line having a length equal to an integral multiple of a quarter of a wave length, and said other value being capacitive and such that the impedance looking into said line at its opposite end is that of a line having length different from said first length by a quarter of a wave length.

FRANKLIN G. PATTERSON.