DIRECTIONAL RADIO ANTENNA LOBE SWITCHING SYSTEM

Filed Aug. 3, 1942 7 Sheets-Sheet 1

FIG. 1

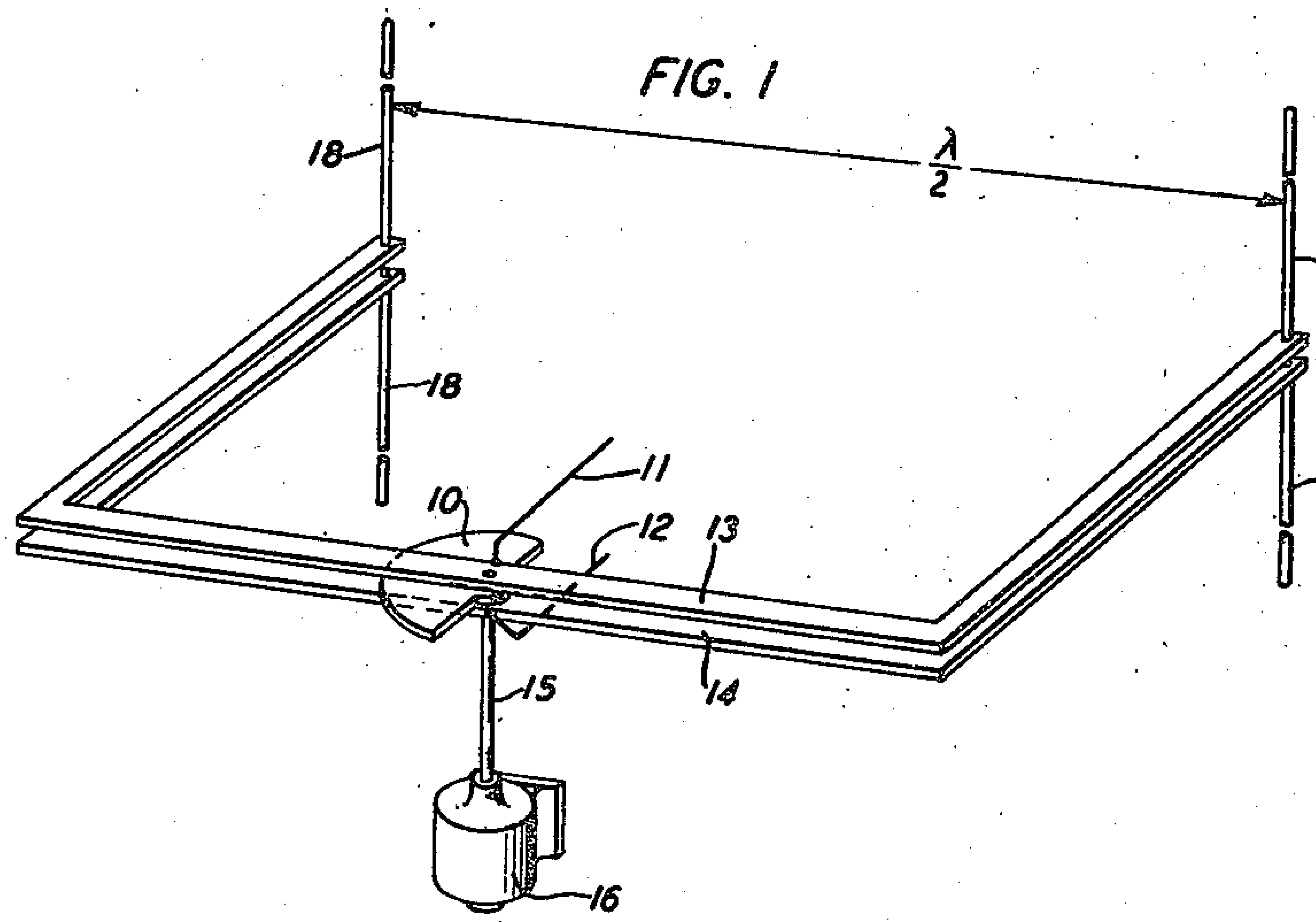

FIG. 2A

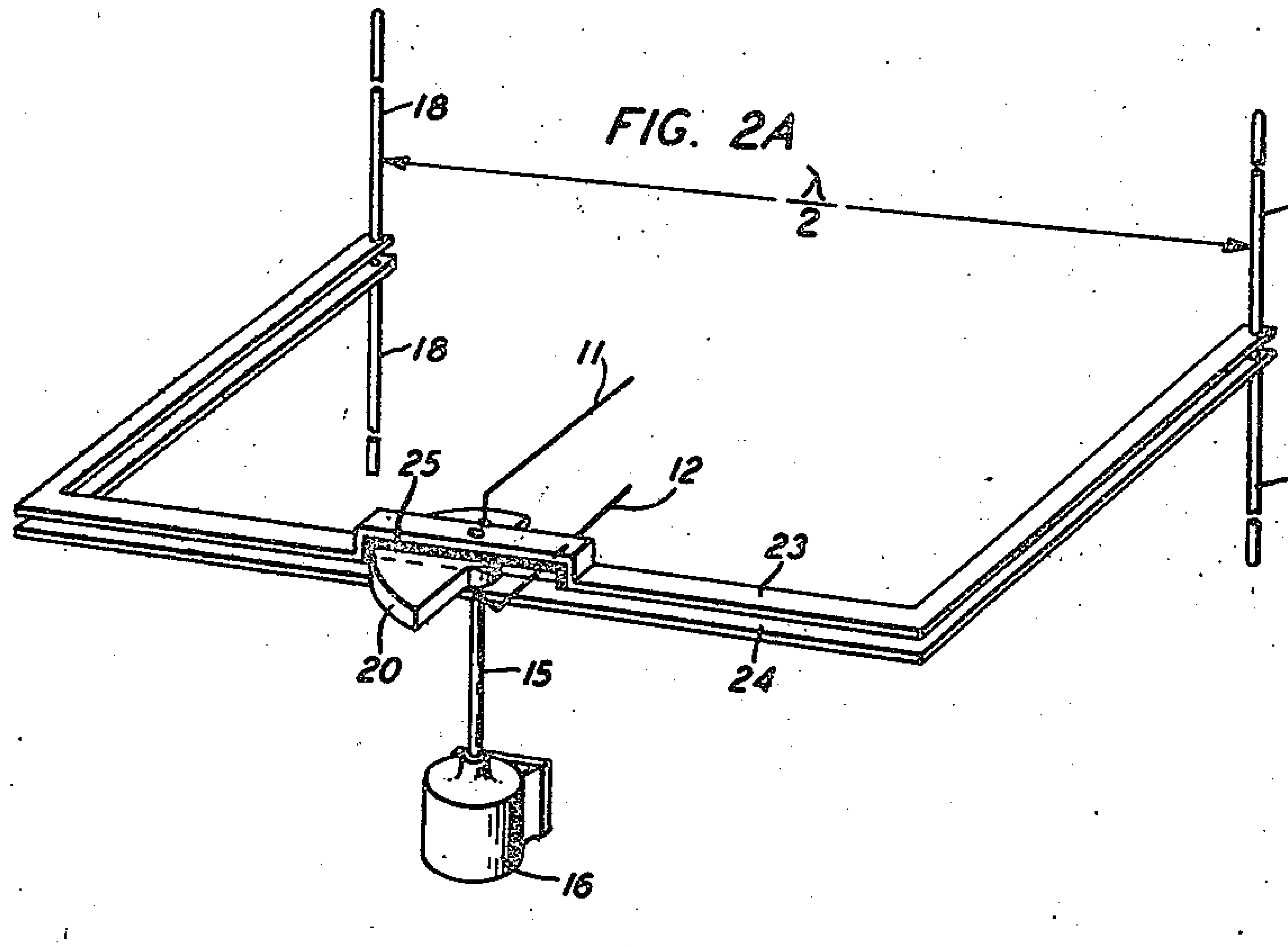

FIG. 2B

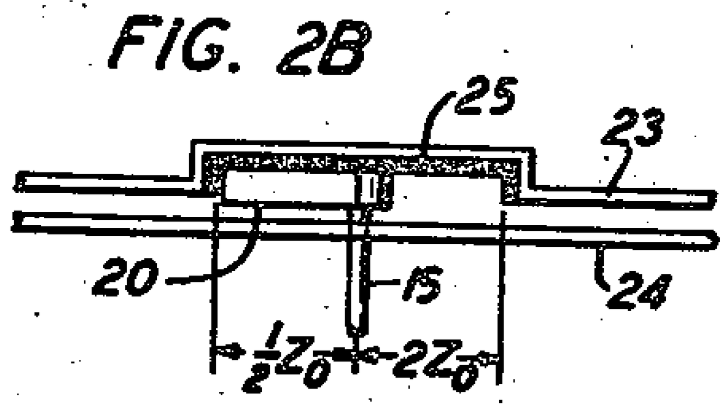

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FIG. 3

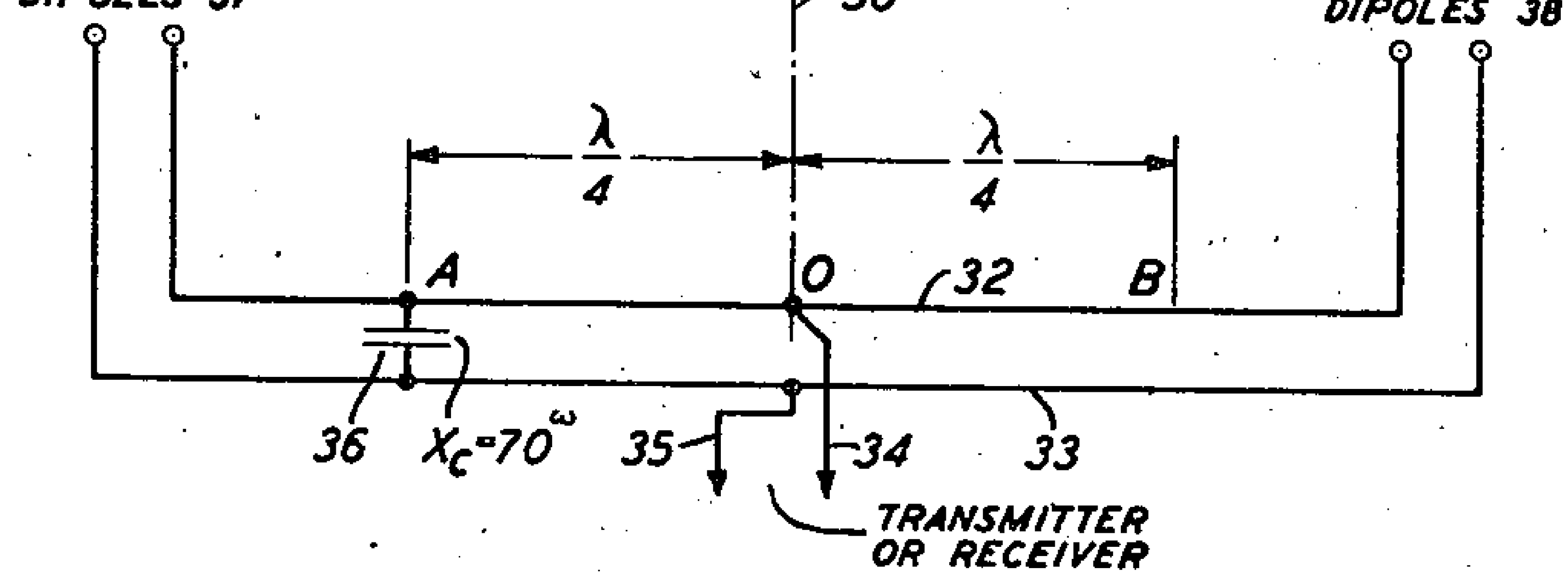

FIG. 4

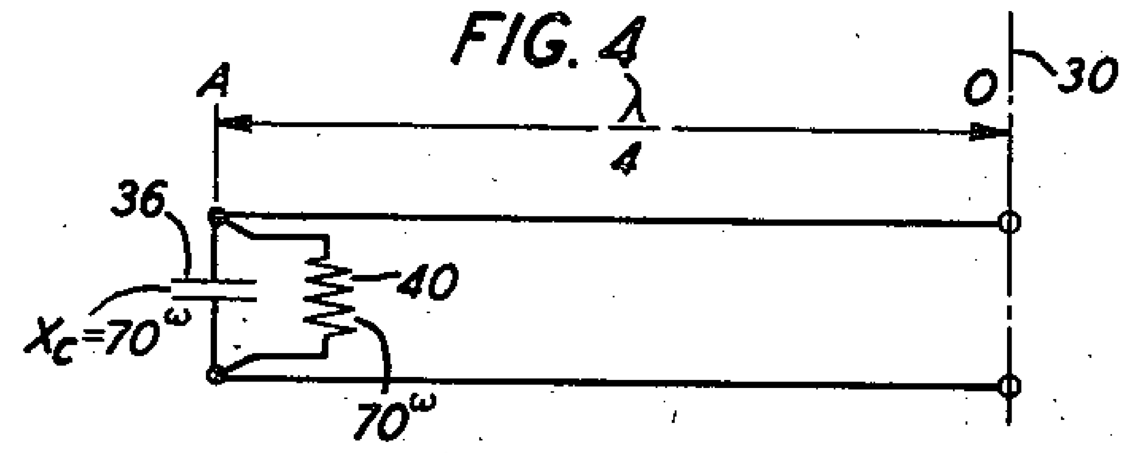

FIG. 5

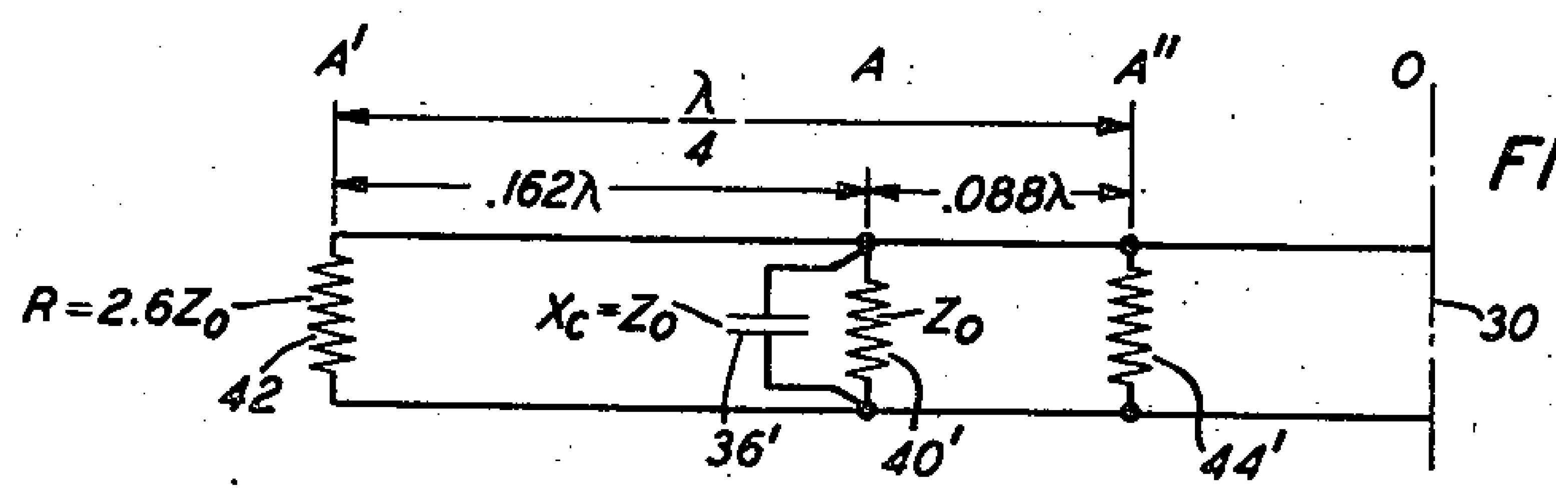

FIG. 6

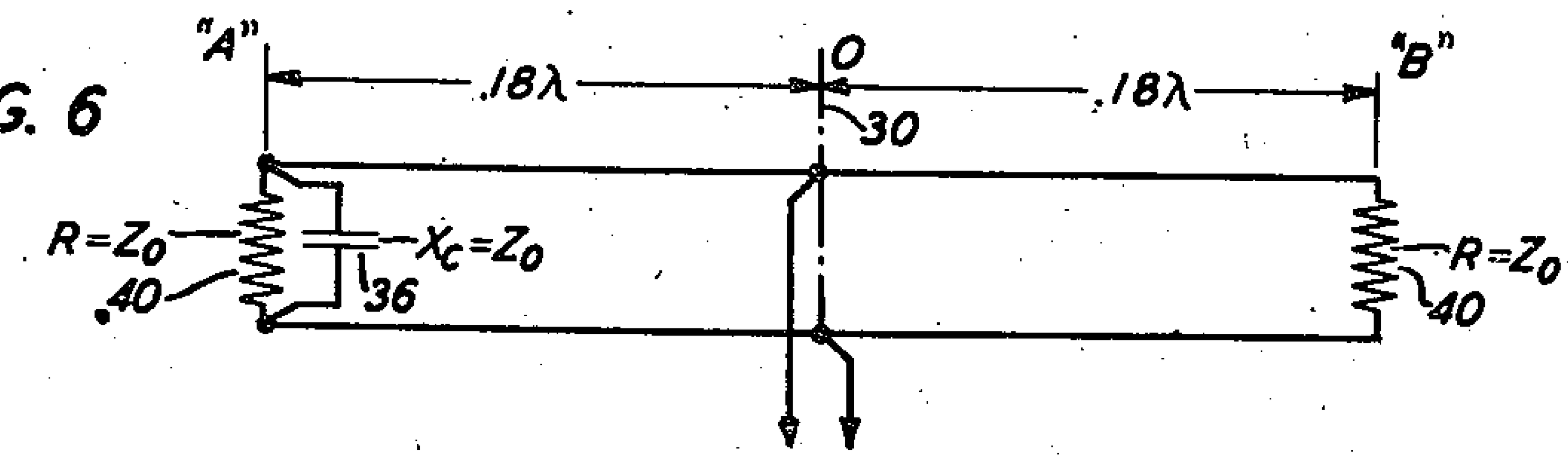

FIG. 7

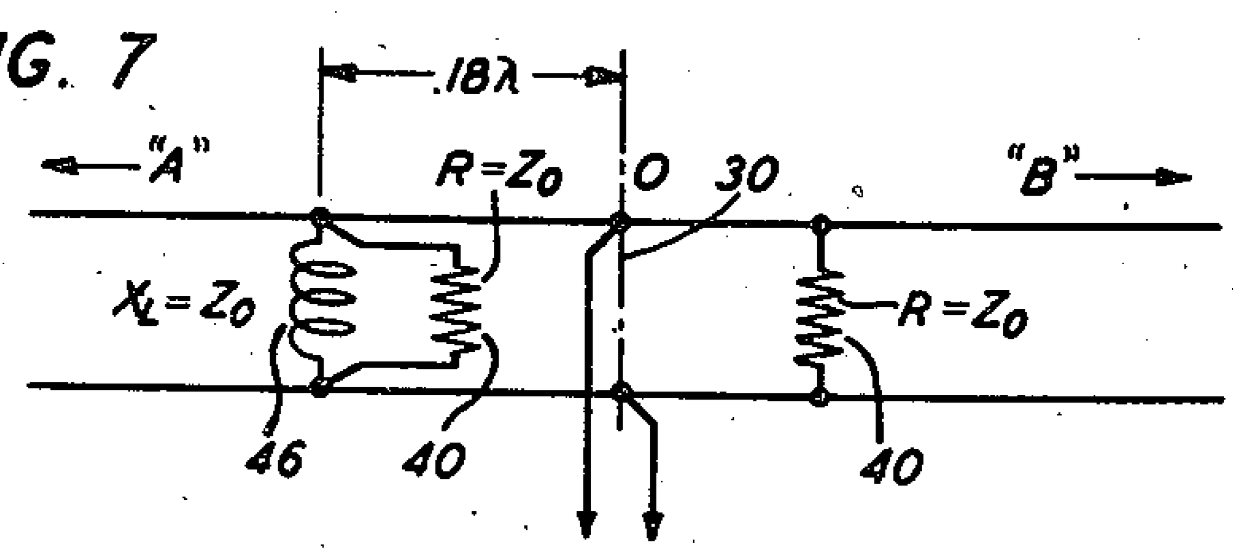

FIG. 8

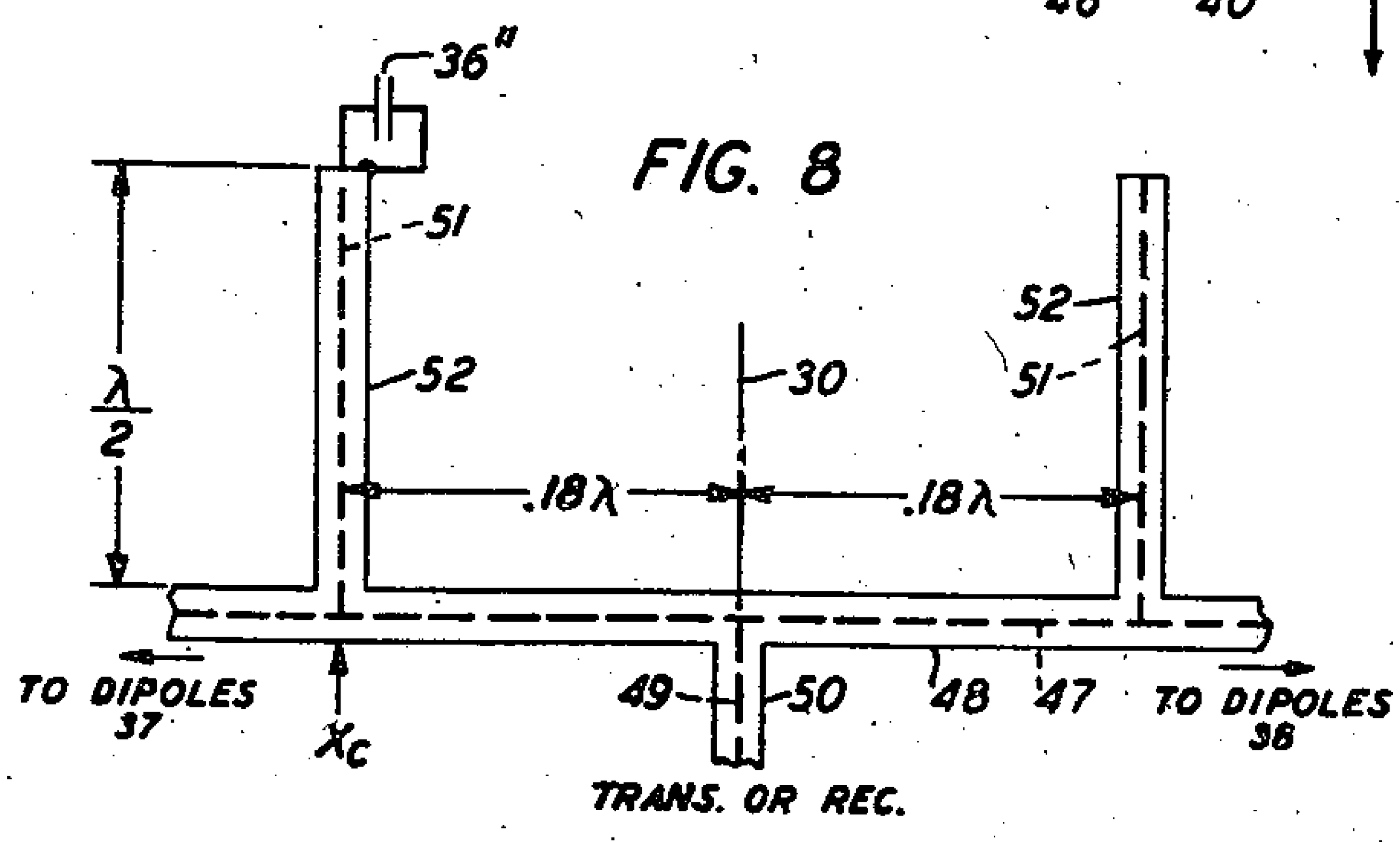

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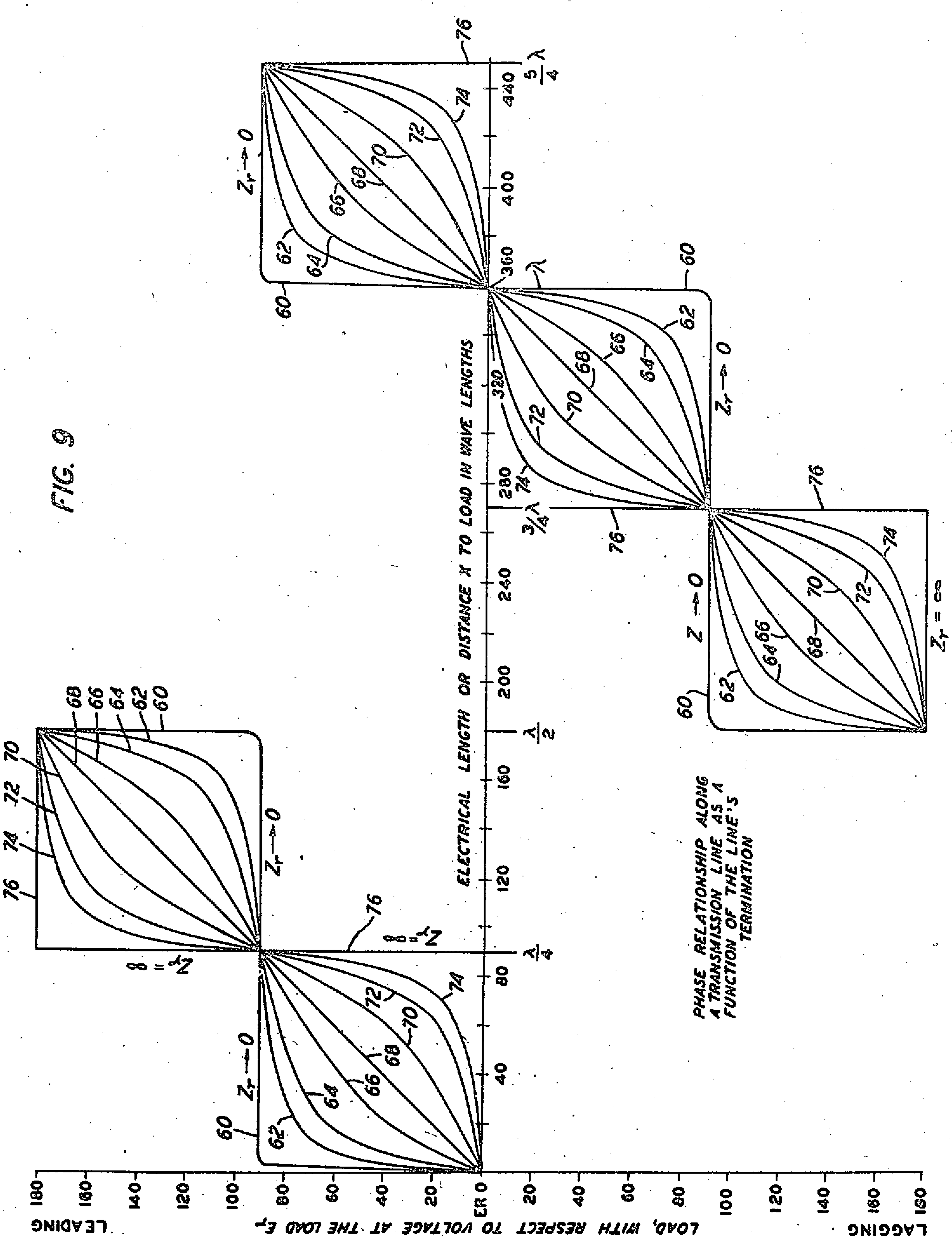
FIG. 9



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DIRECTIONAL RADIO ANTENNA LOBE SWITCHING SYSTEM

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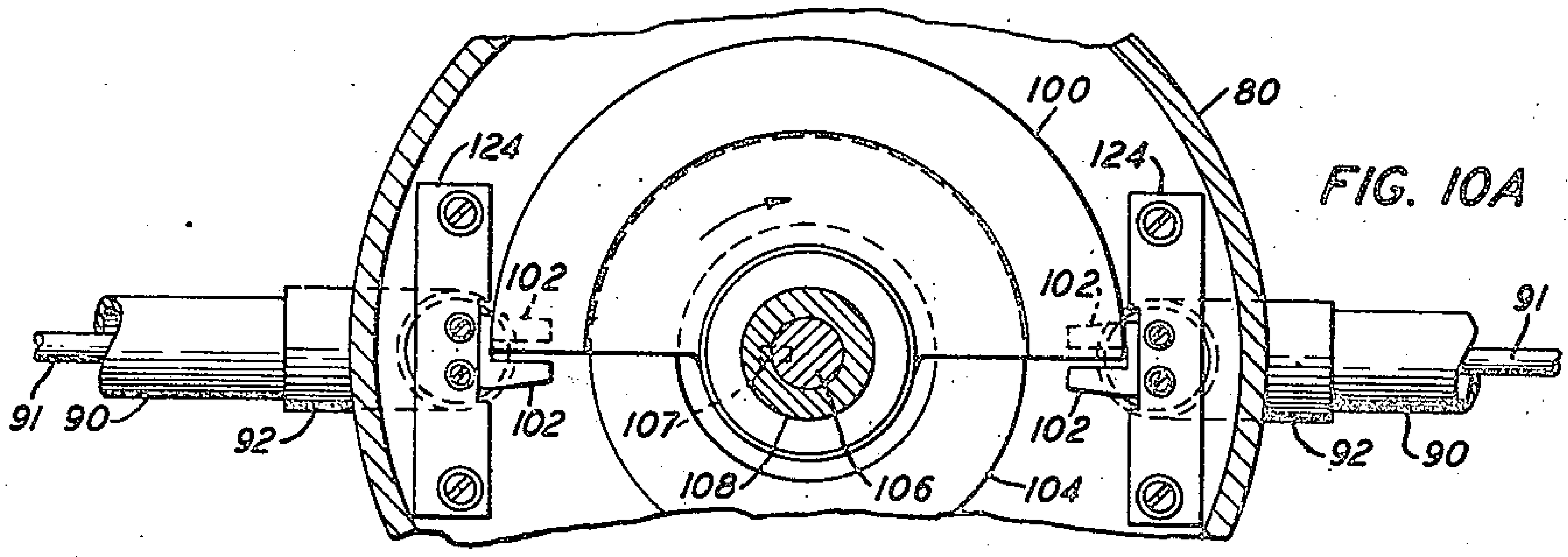

FIG. 10A

FIG. 10C

FIG. 10B

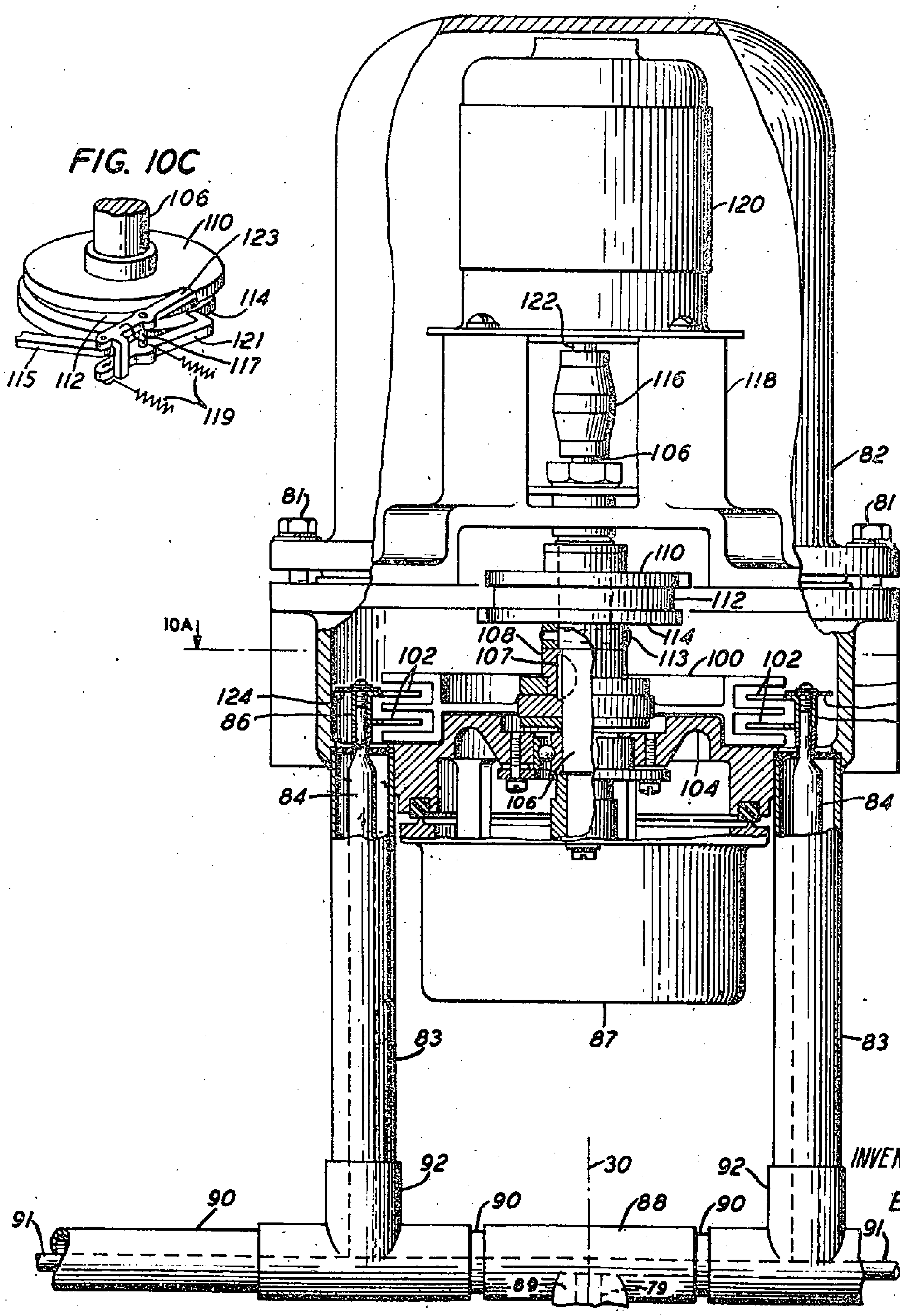

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FIG. 11

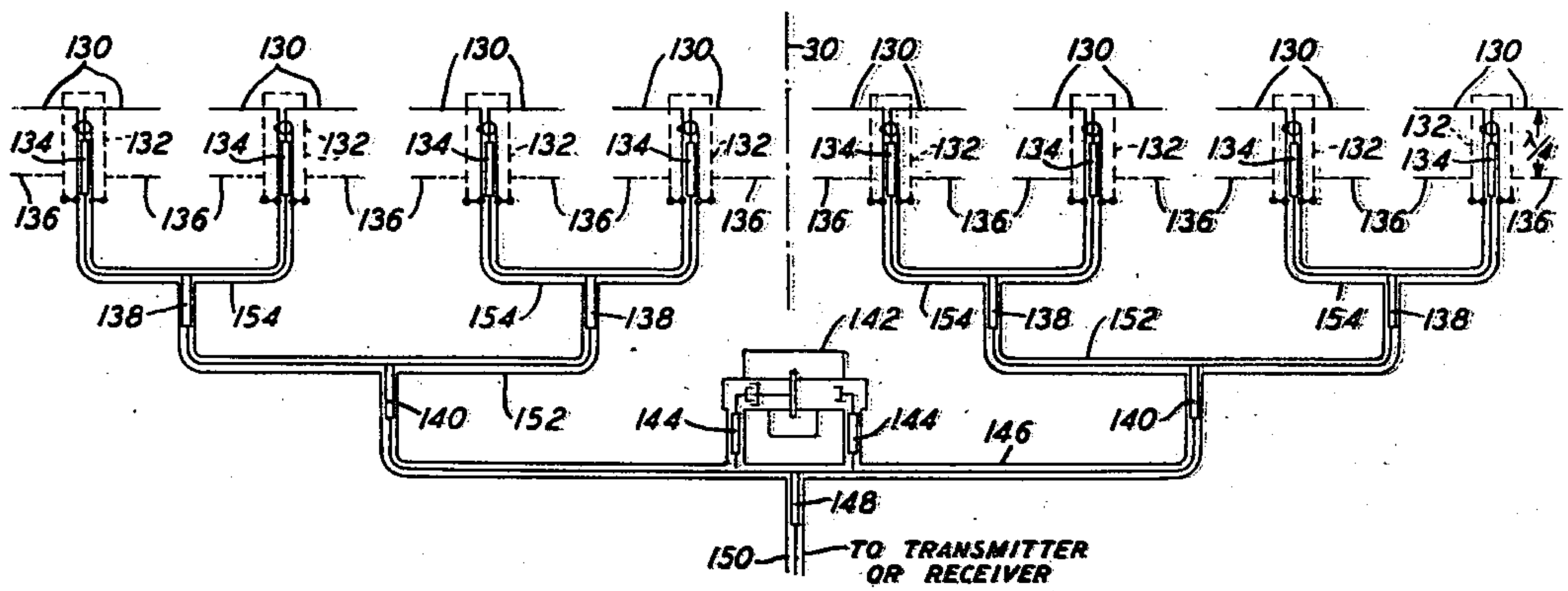

FIG. 12

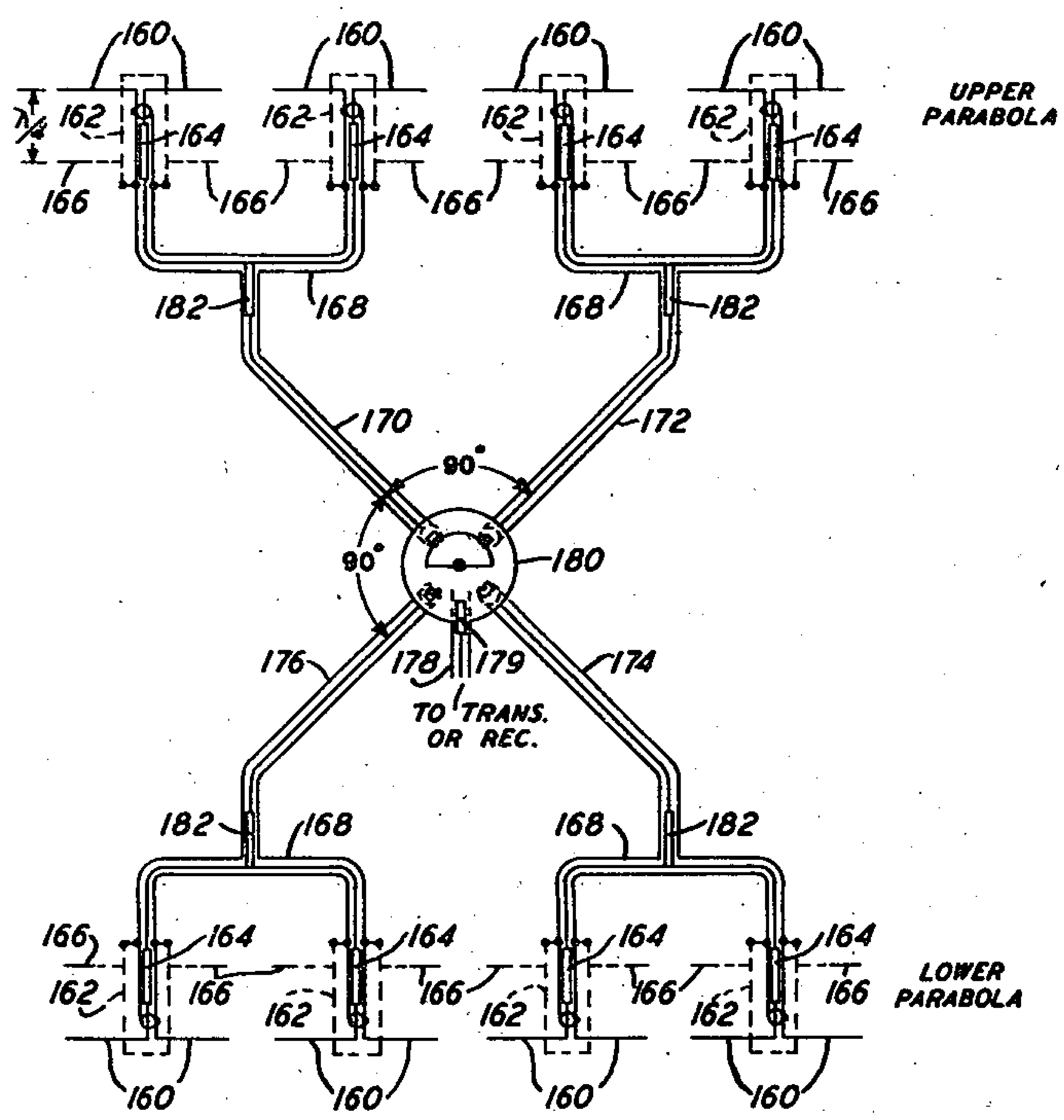

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FIG. 13A

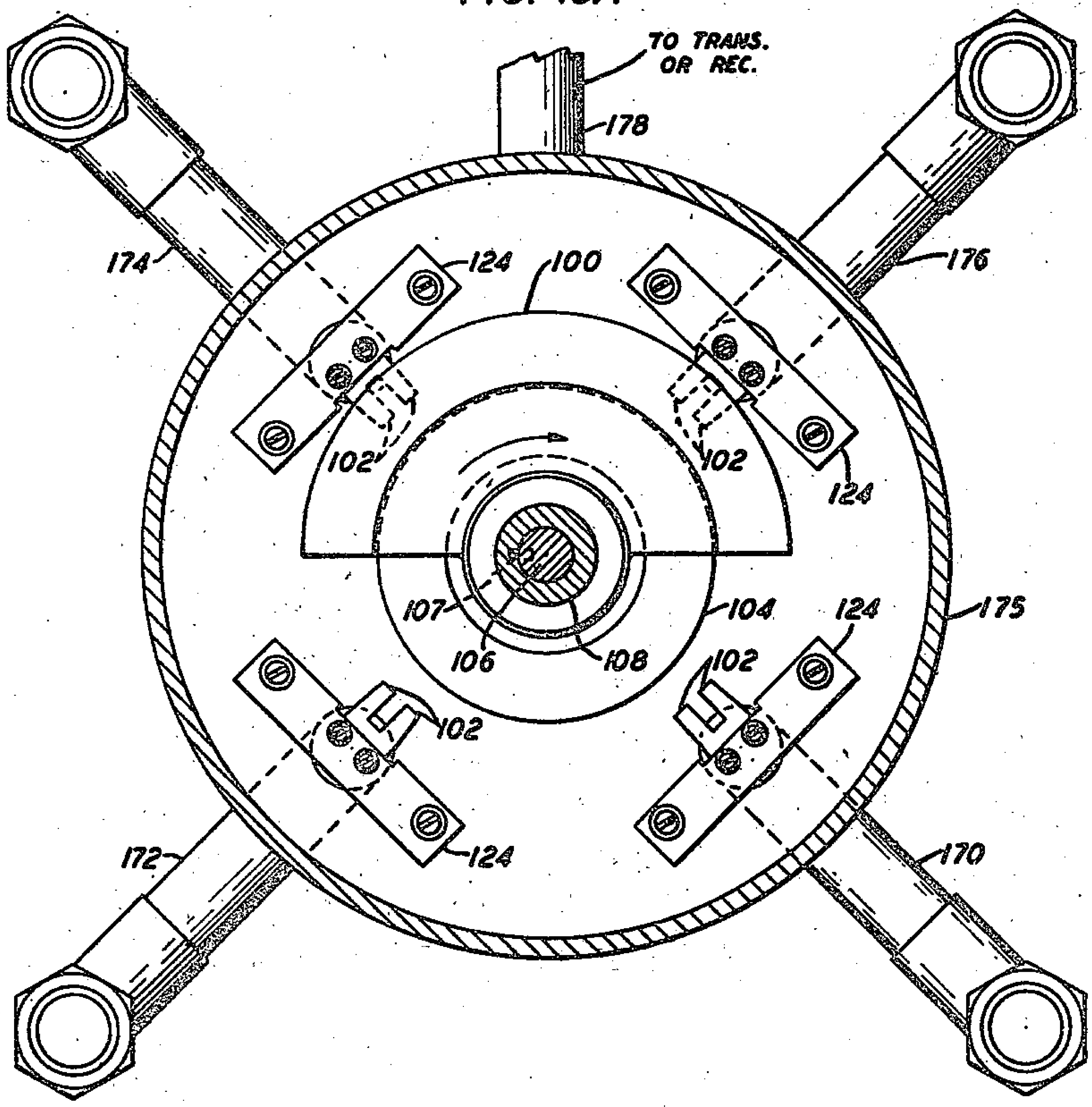
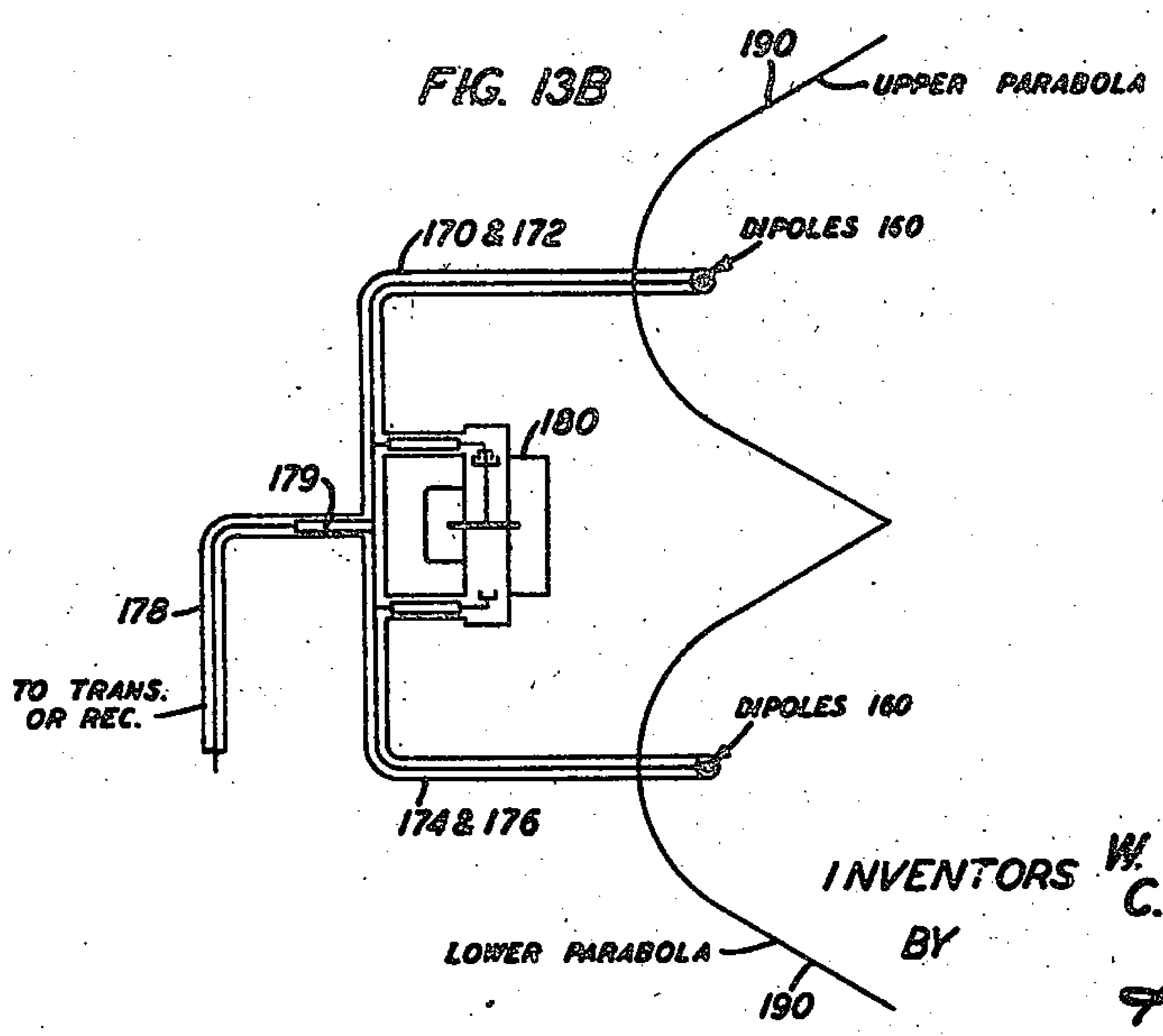


FIG. 13B



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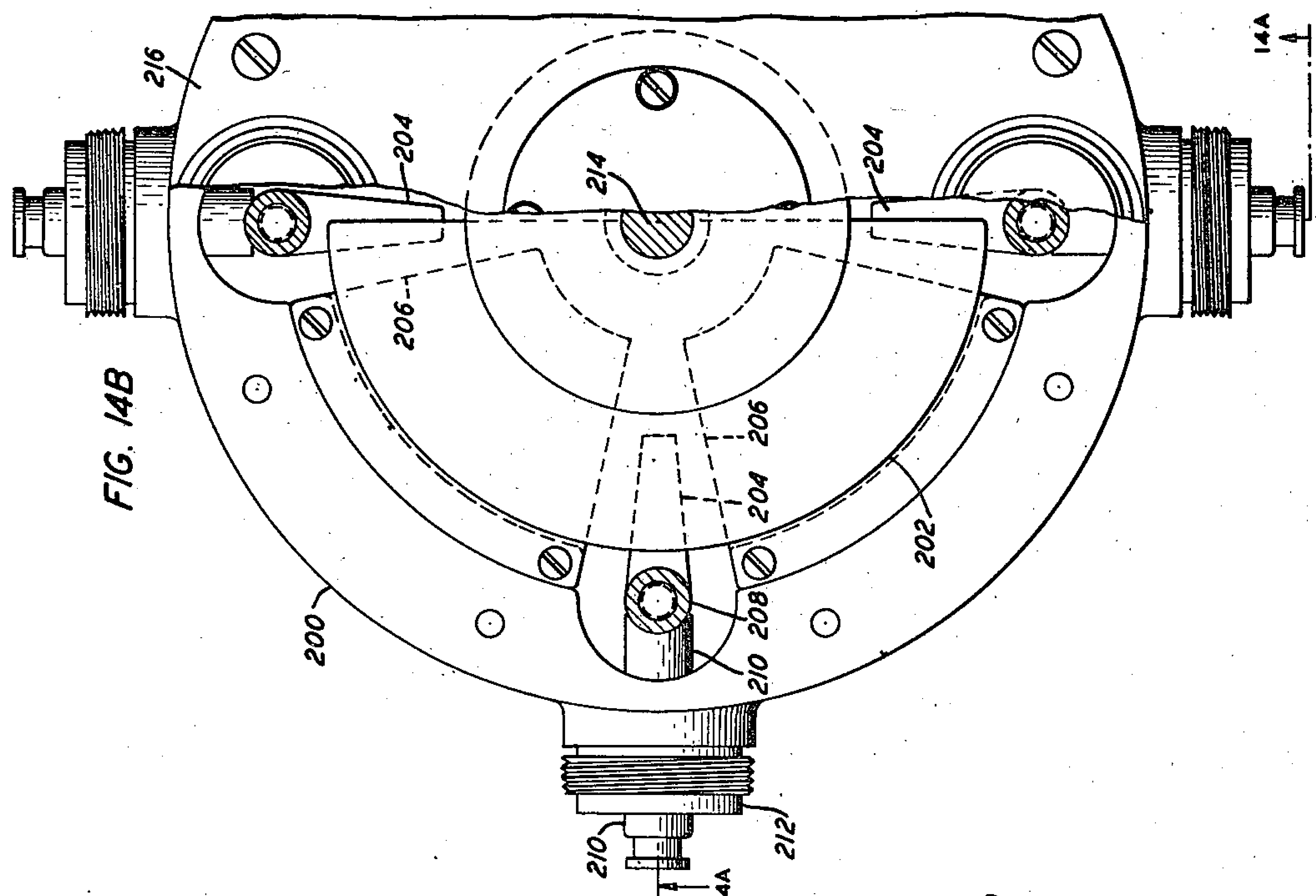

FIG. 14B

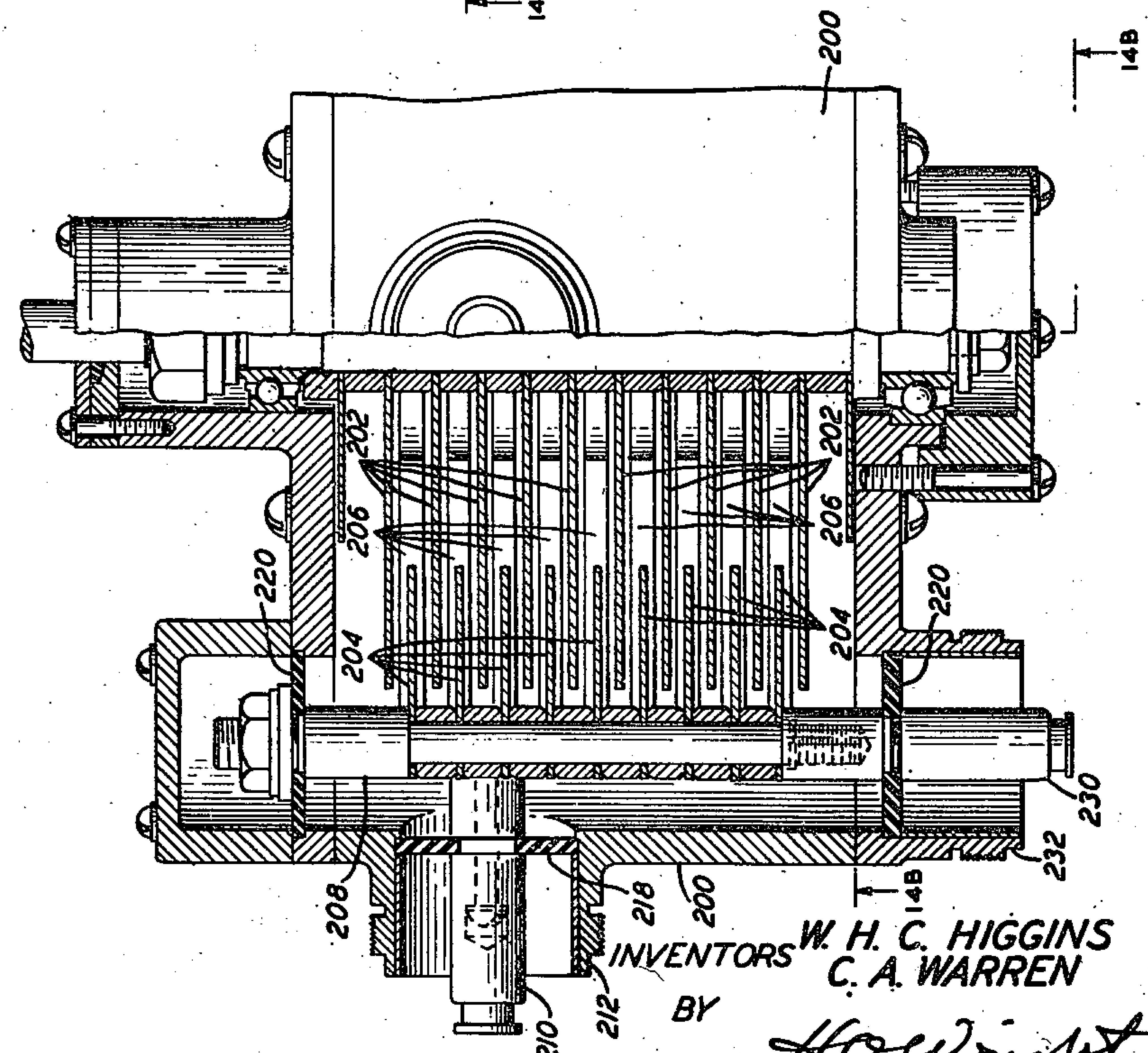

FIG. 14A

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UNITED STATES PATENT OFFICE

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DIRECTIONAL RADIO ANTENNA LOBE SWITCHING SYSTEM

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Application August 3, 1942, Serial No. 453,390

11 Claims. (Cl. 250—11)

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This invention relates to improved high-precision direction finding antenna systems. More particularly it relates to antenna systems having unidirectional, sharply-defined directive characteristics, commonly designated as lobes, and to improved arrangements for "switching" or displacing the unidirectional sharply-defined directive lobe of such antennas alternately between two positions in a given plane, or in each of several planes, a few degrees in opposite directions from the normal axis of directivity, for the purpose of resolving the "flat" bearing obtained with stationary lobe antennas of this type since the differential quotient of the signal strength with respect to the orientation is nearly zero in the neighborhood of maximum reception.

As it is above suggested, the sharpness of the bearing obtained can be increased by switching the lobe alternately from a position a few degrees on one side of its normal axis to a like position a few degrees on the opposite side of the axis. If this is done without affecting the amplitude or shape of the lobe and the shift of the lobe is discretely chosen, a signal of constant intensity will be received i. e. equal signal strength for alternate lobe positions will be obtained when the normal axis of the antenna system is directed precisely at the signal source. The signal source can be a beacon radiator, an ordinary radio transmitter, or an object from which radio waves are being reflected toward the antenna system.

Numerous arrangements for effecting increased sharpness of directive indications by the general method above described, have been devised by others and the present invention is therefore directed toward improved arrangements of this type.

In the prior art, for example, the mechanical (rotary) movement of a reflector to effect "lobe-switching" is taught in Fig. 2 of United States Patent 2,083,242, issued June 8, 1937, to W. Runge. Electrical lobe-switching by conductive contacting devices is taught, for example, in Fig. 3 of the above-mentioned patent and in United States Patents 1,950,708, issued March 13, 1934, to G. Von Arco, 2,046,849, issued July 7, 1936, to W. Runge et al., and 2,160,857, issued June 6, 1939, to A. Gothe.

In general, because of inertia, the mechanical "lobe-switching" schemes of the prior art must operate at relatively slow rates and therefore they are not satisfactory except where the direction indicating signals are of relatively very long duration and of substantially uniform amplitude. Electrical lobe-switching schemes of the prior art,

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are, on the other hand, frequently subject to two sources of difficulty, the first arising from possible poor electrical contacts in switching mechanisms and the second arising from a disturbance of impedance relations as the lobe is switched such that the power distribution throughout the antenna system is changed and the amplitude or shape of the lobe changes as it is switched from one position to the other with the result that the line of precisely equal intensity for the two (or more) lobe positions is not readily determinable. The median line or normal axis of the antenna system, being a conveniently determinable parameter, is preferable as a natural axis of precisely equal intensity for direction finding systems.

In the electrical lobe-switching arrangements of the present invention contact difficulties are avoided by eliminating conductive switching mechanisms. Impedance difficulties of the type described above are avoided by structural arrangements which produce precisely controlled and balanced impedance changes during lobe-switching operations.

The principal object of the invention is, therefore, to provide "lobe-switching" arrangements which will be suitable for obtaining highly accurate bearing indications on signals of relatively very short duration. A further object is to provide lobe-switching arrangements which will be free from electrical contact troubles.

Another object is to provide lobe-switching arrangements which will not objectionally alter the impedance relations within the antenna system, the lobe of which is being "switched."

Other and further objects will become apparent during the course of the following description and in the appended claims. The principles of the invention will be readily understood from the following description of preferred illustrative embodiments in conjunction with the accompanying drawings, in which:

Fig. 1 illustrates one arrangement for lobe switching electrically without employing mechanical contacting members;

Figs. 2A and 2B illustrate a second arrangement for lobe switching electrically without employing mechanical contacting members;

Figs. 3 to 9, inclusive, are diagrams employed in connection with an analysis of the principles involved in an electrical lobe-switching arrangement which provides equal power distribution between the two antenna sections and avoids the use of mechanical contacting members;

Figs. 10A, 10B and 10C illustrate an embodiment of a lobe-switching device of the invention;

Fig. 11 illustrates schematically the use of a single-plane lobe-switching device of the invention with a linear array of eight dipole antennas;

Fig. 12 illustrates schematically the use of a two-plane lobe-switching device of the invention with two linear arrays of four dipole antennas each;

Figs. 13A and 13B illustrate further features of the arrangement schematically indicated in Fig. 12; and

Figs. 14A and 14B illustrate an adaptation of a lobe-switching mechanism of the invention to a relatively lower frequency directional system.

In more detail, in Fig. 1 two dipole antennas comprising radiating members 17 and 18 respectively are spaced one-half wave-length apart so that when energized precisely in phase they will produce a symmetrical directive lobe of radiated energy having a maximum normal to the common plane of the two dipole antennas.

Conducting members 13 and 14 provide identical electrical paths for the transmission of energy to the two dipole antennas from their center points to which a feed line comprising conductors 11 and 12 are electrically connected. A half disc 10 of dielectric material is supported on shaft 15, which is driven by motor 16. Shaft 15 may be of non-conducting material or it may be electrically insulated from conductors 11 to 14, inclusive. As the half disc 10 of dielectric material is rotated about shaft 15 it is introduced alternately to the left and right of the center points of conductors 13 and 14. This is, of course, electrically equivalent to alternately inserting to the left and right of the center point of conductors 13 and 14 a section of transmission line of different impedance from that of the line formed by conductors 13 and 14 and will alternately change the relative phases of the two energy components radiated by dipole antennas 17 and 18 causing the lobe maximum to shift alternately between a position a few degrees to one side of its normal position to one a few degrees to the other side, i. e., the lobe will switch and equal intensities of the two lobes will be received along an axis midway between the two lobe positions. The amount of shift will depend of course upon the radius of the semi-disc 10, its dielectric constant and the change in impedance which it effects. Obviously, such an arrangement will completely avoid contact difficulties.

In Figs. 2A and 2B a somewhat similar arrangement is shown but in this case a semi-disc 20 of metal is employed and the center portion of upper conductor 23 is raised to increase its separation from the lower conductor 24. Shaft 15 is again preferably of insulating material or is insulated from conductors 11, 12, 23 and 24.

As shown in Fig. 2B, metal disc 20 is electrically insulated from conductors 23 and 24, a layer of insulation 25 being inserted in the raised portion of conductor 23 to avoid possible conductive contact. As semi-disc 20 is rotated, it is alternately inserted on the left and right of the center points of conductors 23 and 24 and has the effect as indicated in Fig. 2B of switching alternately from a small section of transmission line having impedance $\frac{1}{2}Z_0$ to a like small section having an impedance $2Z_0$, the dimensions of the over-all arrangement being assumed to have been proportioned so that if conductors 23 and 24 over their major portions have an impedance of Z_0 the section in the center in the absence of the semi-disc 10 will have, because of its greater spacing, an impedance of $2Z_0$ and with semi-disc 10 inserted therein it will have an impedance of $\frac{1}{2}Z_0$. Again the relative phases of the radiations from antennas 17 and 18 will be alternately changed and lobe switching will result, the extent of lobe deflection being a function of the phase change which in turn is dependent upon the radius of semi-disc 10.

The systems of Figs. 1 and 2 are convenient and satisfactory where relatively small shifts of the lobe will suffice, for example shifts in the order of 2 or 3 degrees each side of the normal axis of an antenna array of approximately 4 wave-lengths in breadth. Where larger shifts are desired, however, the impedance may have to be altered ot such an extent that the power distribution between the halves of the antenna array is substantially altered, in which case the shape of the radiated lobe may be adversely affected and the axis of equal intensity for the two lobe positions may be undesirably shifted from the normal axis of the array. Moreover, the axis of equal intensity for one position of the lobe-switching mechanism may not coincide with that for the other position.

To avoid these difficulties, a modified arrangement will be evolved below and the principles upon which it is based will now be discussed.

In Fig. 3 an array of a plurality of dipole antennas, or similar directive antenna units, is assumed to have an axis of symmetry as indicated by center-line 30, one group 37 being to the left and the other group 38 being to the right. Leads 32 and 33 are likewise precisely symmetrical with respect to centerline 30 at which point leads 34 and 35 are connected, bringing power from a transmitter or leading received energy to a receiver.

The impedance of the line formed by conductors 32 and 33 should be substantially equal to that of the dipole antenna groups to which it is connected. For high frequency systems, for example, systems employing energy having a wave-length less than one meter, a convenient impedance is 70 ohms.

For the two ¼ wave-length sections of the transmission line comprising conductors 32 and 33 on each side of the axis of symmetry 30, i. e., a first section extending from axis 30 or point O to point A on the left, and a second section extending from axis 30 or point O to point B on the right, the phase shift of each of these sections, assuming condenser 36 to be temporarily disconnected, is ¼ of 360 degrees or 90 degrees. This follows from the well-known fact that a uniform transmission line terminated in its own impedance has a phase shift of 360 degrees per wave-length.

Assuming now that condenser 36 is connected across the line at point A, the section O—A represented in Fig. 4 is obtained. The capacity of condenser 36 is chosen so that its impedance at the operating frequency of the system is $-j$ 70 ohms, i. e., a negative purely reactive impedance of 70 ohms. In Fig. 4 resistance 40 represents the remainder of the system to the left of point A and is assumed to be substantially 70 ohms and purely resistive.

Next, consider a section of line having a Z_0 of 70 ohms as shown in Fig. 5. By standard formulae, if the line is terminated at its left end A′ by a pure resistance 42 equal to 2.6 Z_0, at a point A .162 wave-length from this resistance 42 the impedance is equivalent to a resistance Z_0 and reactance $-Z_0$ in parallel, i. e., an impedance equivalent to that of a capacity 36′ and a resistance

40′ in parallel, will be found. It should be understood that capacity 36′ and resistance 40′ represent the impedance of the line at point A of the line of Fig. 5 and are not discrete elements. In other words, in Fig. 4 we could remove condenser 36 and resistance 40 and substitute therefor an additional section of line .162 wave-length long with a resistance of 2.6 Z_0 shunting the far end. This process of analysis discloses reference points at which purely resistive impedances exist and from which the phase shift along the section of Fig. 4 may be determined. By standard formulae, another purely resistive impedance point A″ on the line of Fig. 5 which is ¼ wave-length from A′ is found and the impedance of the line at this point A″ is found to be .38 Z_0. On the basis of this information the curves of Fig. 9 can be used to determine the phase shift of the section of line shown in Fig. 4.

In Fig. 9 the electrical length or distance along the line from a point X to a load or impedance across the line is given in degrees, one wave-length being 360 degrees. Values of load impedances Z_r between $Z_r=0$ and $Z_r=\infty$ are indicated for curves 60, 62, 64, 66, 68, 70, 72, 74 and 76, curve 60 corresponding to $Z_r=0$, curve 62 corresponding to $Z_r=\frac{1}{10}Z_0$, curve 64 corresponding to $Z_r=\frac{1}{5}Z_0$, curve 66 corresponding to $Z_r=\frac{1}{2}Z_0$, curve 68 corresponding to $Z_r=1Z_0$, curve 70 corresponding to $Z_r=2Z_0$, curve 72 corresponding to $Z_r=5Z_0$, curve 74 corresponding to $Z_r=10Z_0$ and curve 76 corresponding to $Z_r=\infty$, respectively.

The phase shift corresponding to a particular length of line and termination may then be read from the scale at the left of Fig. 9.

For example, in the above case where the length of line was .162 wave-length or 58.4 degrees (electrical length) and the termination or load was 2.6 Z_0 the curves of Fig. 9 show that the phase shift from A to A′, Fig. 5, is 32 degrees. Since the phase shift from A′ to A″ is 90 degrees the phase shift from A to A″ Fig. 5 is 90−32=58 degrees.

In the same manner considering the section of line from center-line 30 to A, Fig. 5, the effective termination at A″ is, as above stated, .38 Z_0 and its distance from center-line 30 is ¼ wave-length minus .088 wave-length equals .162 wave-length. From the curves of Fig. 9 the phase shift from center-line 30 to A″ is 74 degrees. The total phase shift from center-line 30 to point A, Fig. 5, is then 132 degrees (58+74) and the difference in phase shift between the sections to points A and B on opposite sides of the center-line 30 in Fig. 3 is then 132−90=42 degrees. This demonstrates that a substantial phase shift can be conveniently introduced by merely shunting a capacity across the line comprising conductors 32 and 33 of Fig. 3 at a distance which is short with respect to the wave-length from the center line 30.

By further adjustment of the position of capacity 36 it was found that for a distance of .18 wave-length from the center-line 30, as illustrated in Fig. 6 the parallel resistive components of the impedances looking each way from the center-line 30 toward the dipoles 27 and 28 respectively were both the same and were equal to the characteristic impedance Z_0 of the line comprising conductors 32 and 33. This feature assures equal power division in the two branches. Furthermore, the phase shift in the branch including capacity 36 is found for this condition to be 54 degrees greater than for the branch having no capacity therein. This phase shift is greater

than that for a spacing of the condenser of ¼ wave-length from the center line and, as will be described hereinunder, lends itself very conveniently to a lobe-switching arrangement which will alternately insert a capacity equivalent to capacity 36 in first the one and then the other of the two branches leading to the two groups of dipoles, the capacity in each case being at an electrical distance of .18 wave-length from the center line of electrical symmetry. Moreover, equal power distribution and therefore substantially zero lobe distortion is realized by this arrangement.

Alternatively, an inductive reactance equal to $+jZ_0$ could be substituted for the capacity 36 as illustrated by inductance 46 of Fig. 7 and if placed at .18 wave-length from the center line of symmetry would produce equivalent results, except that the lobe shift would be in the opposite direction. Such an arrangement would, however, usually involve conductively contacting switching members to effect lobe switching. Such arrangements are preferably to be avoided if possible. It would of course be feasible to inductively couple an inductive reactance alternately to corresponding points on opposite sides of the line of symmetry but in most instances it is more convenient to employ capacitative reactances as described in detail below.

Fig. 8 illustrates a circuit of the same type as shown in Fig. 3 except that it employs concentric rather than simple two-conductor transmission lines and the capacity 36″ is applied to a section of line ½ wave-length long comprising conductors 51 and 52, this section in turn connecting to the main horizontal line comprising conductors 47 and 48, at a point which is electrically .18 wave-length from the center-line 30 of electrical symmetry of the system. As is well known in the art, this is electrically equivalent to connecting capacity 36″ directly across line 47, 48 at the .18 wave-length point, but as will presently become apparent the use of the ½ wave-length stub 51, 52 lends itself more conveniently to use in a practicable mechanism for effecting lobe switching in accordance with the principles of the invention.

In Figs. 10A and 10B a practicable mechanism for effecting lobe switching in one plane is illustrated. In Fig. 10B a concentric line system comprising a T-fitting 88, two T-fittings 92 and units of coaxial line 90 including inner conductor 91, joining the three above-mentioned T-fittings 88 and 92 and extending to the left and right from T-fittings 92 (shown in Fig. 10A) is shown, together with two stub concentric line members comprising outer conductors 83 and inner conductors 84 are shown.

This concentric line system is of the type shown in Fig. 8 and described above.

The vertical stub lines 83 and 84 are each ½ wave-length long and are made to have a lower characteristic impedance than the concentric line 90 and 91 so that the stray capacity of the metallic fingers 102 do not appreciably affect the electrical length of the line. The upper ends connect electrically to mounting members 86 and through the last-stated members to metallic finger members 102, the latter members having a central portion removed as shown in Fig. 10A to facilitate centering the beam of the antenna when the lobe-switching device is not being used, as will be explained in more detail presently. An insulating member 124 provides mechanical support for the upper end of member 88 in each instance.

The concentric line 90, 91 extends to the left and to the right from T-members 92, respectively, to connect to the left and right halves of the antenna system in accordance with the arrangement schematically indicated in Fig. 3 above. The centerline 30 of electrical symmetry for the system passes through the center of T-member 88 as shown in Fig. 10B, the vertical leg of T-member 88 serving to connect to transmitting or receiving apparatus or to a duplexing arrangement where the antenna system is to be employed alternately for transmitting and receiving. An impedance matching member 79 comprising an enlarged section of the inner conductor is provided in the vertical leg of the T-member 88. Like impedance matching sections are employed at other points in the multiple antenna arrangements to be described hereinunder. The principles involved in the use of such impedance matching members are well known to those skilled in the art and are, briefly, when a load impedance differs by a moderate amount from the characteristic impedance of the line it is possible to transform the load impedance to the characteristic impedance of the line by connecting the two with a quarter wave-length transmission line having a characteristic impedance of $\sqrt{Z_r Z_0}$ where Z_r is the load impedance and Z_0 is the characteristic impedance of the transmission line to which the load is to be matched.

A semicircular rotor member 100 of conductive material having a vertical web with three horizontal semicircular fins extending therefrom, as shown in plan view in Fig. 10A and in elevation in Fig. 10B, is fastened to shaft 106 by key 107. The horizontal fins of member 100 interleave in spaced relation with the metallic finger members 102 as shown in Fig. 10B as the rotor 100 is rotated forming a capacity which for alternate half rotations is transferred from the end of one of the vertical stub lines 83, 84 to the end of the other vertical stub line. When the finger members 102 are fully interleaving the webs of member 100 the capacity between them is such that its reactive impedance as seen from the point of connection between line 90, 91 and the vertical stub lines 83, 84, will be equal to the characteristic impedance of line 90, 91. The points at which the stub lines connect to line 90, 91 are of course .18 wave-length to the left and right of the center line of electrical symmetry 30, respectively, so that, in accordance with the theory discussed in detail hereinbefore, a discrete phase shift will alternately be introduced to the left and right of axis 30 without disturbing the power distribution to the two halves of the antenna system.

Rotor 100 has, as shown in Fig. 10B, very small clearance with respect to the lower surface 104 of its housing member 89 which provides a relatively very low impedance path (high capacity) for high frequency currents and effectively short-circuits at high frequencies the relatively high resistance of the conductive path through the rotor and the rotor shaft and bearings to the housing 89, to which the outer conductors 83 of the stub lines connect.

Motor shaft 122 of motor 120 is coupled through flexible coupling 116 to shaft 106 and serves, of course, to drive rotor 100. Motor 120 is supported on a mounting bracket 118 and enclosed by housing member 82 which is secured to the lower housing member 80 by bolts 81.

Members 110, 112 and 114 and associated details shown in Fig. 10C comprise a stopping mechanism for stopping the lobe-switching rotor 100 precisely in the position in which it is shown in Fig. 10A. This position is chosen since it provides equal capacities at the upper ends of the two stub lines 83, 84 completing the electrical symmetry of the antenna system so that maximum radiation or reception will coincide with the normal axis of the antenna array when the lobe-switching mechanism is not in use.

Members 110 and 114 are single-tooth ratchet type cams. Member 114 is keyed to shaft 106 by taper pin 113. Member 110 is free to turn on shaft 106. Member 112 is a spiral type flat spring similar to the main springs employed to drive large clocks and is fastened at one end to member 110 and at its other end to member 114. When power is removed from the motor 120 to stop the lobe-switching action, a solenoid, not shown, whose winding is connected across the motor winding is deenergized to release member 115 of Fig. 10C and permit springs 119 to move pawls 121 and 123 against members 114 and 110, respectively. The tooth of member 110 engages pawl 123 and ceases its rotation. The inertia of motor 120, rotor 100 and shaft 106 is then expended in winding up spring 112 until shaft 106 is brought to a stop whereupon spring 112 starts to rotate shaft 106 in the opposite direction until pawl 121 engages the single tooth of member 114 stopping shaft 106 in the position shown in Fig. 10A. The space between fingers 102 permits small variations in the position of rest without seriously affecting the electrical balance of the system and thus makes it possible to employ reasonable tolerances in manufacturing the parts of the stopping mechanism. When power is again applied to motor 120 the solenoid withdraws the pawls from members 110 and 114 and permits free operation of the lobe-switching mechanism.

Housing 87, directly under the lobe-switching rotor 100, encloses a simple cam-operated switching mechanism, the cams being driven by an extension of shaft 106, the position of the cams indicating by closing appropriate circuits and opening others, the direction in which the lobe is being deflected at any particular instant during operation of the lobe-switching mechanism. This arrangement is employed usually to provide a double image of a signal of particular interest on the indicator, which is usually a cathode ray oscilloscope, one image being the signal as received with the lobe switched in one direction, the other image being the signal as received with the lobe switched in the other direction, the two images being laterally displaced a short distance so as to appear side by side whereby the antenna system may be turned until the two images are of equal amplitude and the antenna system will then be pointing directly toward the source from which the signal of particular interest is being received.

Details of this arrangement are not illustrated in the drawings of this application since it does not relate directly to the invention for which protection is being sought. However, the above brief description will, it is felt, suffice to substantially assist in making clear the advantages to be gained by the use of lobe-switching arrangements in radio direction determining systems.

Fig. 11 shows in schematic diagram form an antenna array arranged for single-plane lobe-switching in accordance with the principles of the invention. In Fig. 11 eight dipole antennas

130 are shown aligned end to end in a row with uniform spacing between antennas. The length of each radiator of the dipoles 130 is preferably a half wave-length of the frequency to be employed. The system is electrically symmetrical with respect to the axis 30. Enclosure 132 is for the purpose of providing a balanced to ground feed for dipoles 130 by making the impedance of the outer conductor of coaxial line 154 high with respect to ground at the point where the dipole connection is made. Members 136 are reflectors spaced ¼ wave-length behind the dipoles 130 and as is well known in the art increase the efficiency and directivity of their associated dipoles. Members 134, 138, 140, 144 and 148 comprise enlarged sections of the inner conductor of their respective concentric lines and function as above described to improve the impedance matches at the junctions where they are situated.

Member 142 is a lobe-switching mechanism, preferably of the type illustrated in Figs. 10A and 10B and described in detail above.

In a further form of the arrangement of Fig. 11 the individual reflectors 136 can be replaced by a single semi-cylindrical reflector of parabolic cross section, the line of antennas being situated along the focal line of the reflector. Reflectors of this type are indicated in Fig. 13B for a two-plane lobe-switching system and are described below.

Fig. 12 shows in schematic diagram form an antenna array arranged for two-plane lobe switching in accordance with the principles of the invention. Figs. 13A and 13B illustrate further features of the arrangement of Fig. 12. The array of Fig. 12 is similar to that of Fig. 11 except that two rows of dipoles 160 are employed, one row being positioned above the other so that by alternately introducing additional phase shift in the lines leading to the upper and lower rows the lobe can be switched in the vertical plane. The rows are each subdivided horizontally into two equal parts and by alternately introducing additional phase shift in the lines leading to the right and left halves respectively of both rows the lobe can be switched in the horizontal plane. As for Fig. 11, so in Fig. 12, each dipole 160 is provided with reflectors 166 which can be individual or which can be replaced by a single semicylindrical reflector of parabolic cross section for each row of dipoles as indicated in Fig. 13B. Enclosures 162 are provided around the end of each line adjacent to a dipole antenna and impedance matching elements such as 164, 182 and 179 are provided at the several line terminals as for the system of Fig. 11.

As a matter of mechanical convenience the lobe-switching mechanism 180 of Fig. 12 can be, in the majority of its structural details, very much like the lobe-switching mechanism described above and illustrated in Figs. 10A and 10B. The chief and sole important difference will of course follow from the necessity of lobe switching in two planes and as indicated in Figs. 12 and 13A four sets of members 102 spaced at 90-degree intervals with respect to each other and connected by half wave-length concentric line stubs to the four branch lines 170, 172, 174 and 176 respectively at a distance of .18 wave-length from the center of electrical symmetry of the system are employed, in lieu of two sets of members 102 spaced at 180 degrees from each other as for the single plane arrangement of Figs. 10A and 10B.

The rotor 100 may be identical with that employed for single-plane operation and as it rotates it will engage successive pairs of adjacent sets of members 102. Starting from the position indicated in Fig. 12 and assuming clockwise rotation, the beam for the position indicated in Fig. 12 will be deflected up; as the rotor turns to engage members 102 of line 174 and drops member 102 of line 170 the beam will be deflected to the right; as the rotor proceeds further to engage members 102 of lines 174 and 176 only the beam will be deflected down and finally when the rotor is engaging members 102 of lines 176 and 170 only the beam will be deflected to the left.

A stopping mechanism is preferably provided to stop the rotor at a position in which the beam is deflected up, i. e. with the rotor approximately 180 degrees from the position indicated in Fig. 12, when it is desired to operate without lobe switching.

The cam-operated switches cooperating with the indicating system for a two-plane lobe-switching system such as that illustrated by Fig. 12, preferably connect a left-right indicator for the left and right beam deflections and an up-down indicator for the up and down beam deflections respectively, so that a signal of particular interest may be located and followed in azimuth employing the left-right indicator and in elevation by employing the up-down indicator.

In the side view schematic diagram of Fig. 13B, the upper and lower dipole arrays of Fig. 12 are shown aligned on the focal lines of upper and lower semicylindrical reflectors 90 of parabolic cross section, respectively. Lines 170 and 172 will in this view lie in a common plane as will also lines 174 and 176.

In Figs. 14A and 14B the details of a capacity switching unit for a lobe-switching mechanism intended for use in a relatively low frequency (200 megacycles) and low impedance system are shown. In this system larger capacities are required so that the rotor 202 for the unit of these figures comprises ten capacity members in the form of semicircular plates, and the finger members 204 are assembled in groups of nine interleaving in spaced relation with the rotor plates. To obtain the high capacity (low impedance) desired between the rotor 202 and the housing 200 in this instance, a set of nine members 206 fastened to the housing 200 is provided to project in interleaved arrangement spaced with respect to rotor elements 202 as shown in Fig. 14A and spaced between each pair of the sets of finger members 204 as shown in Fig. 14B. Because of the lower frequency, also, the distance of the .18 wave-length points from the electrical center of symmetry for the antenna and lobe-switching systems is great enough so that the half wave-length stub lines of the higher frequency systems may be omitted and the four branch lines may be brought directly to the lobe-switching mechanism from the center of symmetry and proceed from the mechanism to their respective subgroups of the antenna array. For example, in Fig. 14A the bottom end 230 of member 208 at the left of the figure may connect to the inner conductor of a length of line .18 wave-length long coming directly from the electrical center of symmetry and a second connection to member 208 may be made, as by member 210, from which the inner conductor of a line to one subgroup of the antenna array may be connected. Members 218 and 220 serve to insulate the assembly supported on member 208 from housing 200 and threaded extensions 212 and 232 of housing 200 facilitate the fastening of the outer conductors of the respective concentric lines to the housing 299. In other respects the lobe-switching mechanism and associated circuit arrangements of Figs. 14A and 14B may be substantially the same as for similar mechanisms and arrangements described in detail above for higher frequency systems.

Numerous other arrangements embodying the principles of the invention will occur to those skilled in the art. The scope of the invention is defined in the following claims.

What is claimed is:

1. In a high frequency radio directional system, an antenna system comprising a plurality of radiating and receiving antenna members symmetrically arranged with respect to a particular axis, a system of electrical transmission lines providing electrical symmetry between a common electrical input point and the corresponding portions of said antenna system on opposite sides of said axis of symmetry, the antenna system being proportioned to provide a sharply directive lobe characteristic along said axis of symmetry and lobe-switching means comprising means for introducing a predetermined discrete reactive impedance non-conductively connecting to said antenna system, alternately at two portions of said transmission line system, said two portions being the corresponding portions of said transmission line system on opposite sides of said axis of symmetry, the value of said reactive impedance being not less than the characteristic impedance of said transmission line whereby lobe-switching, that is deflection of the lobe alternately from a position a few degrees on one side of said axis of symmetry to a position a like few degrees on the opposite side of said axis, can be effected with rapidity and without encountering contact resistance difficulties.

2. The arrangement of claim 1 the point of introduction of said discrete reactive impedance being chosen to provide substantially no disturbance of the normal equal distribution of power to the portions of said antenna system on both sides of said axis of symmetry when said impedance is introduced on either side of said system whereby the shape of the lobe characteristic of said antenna system is not altered by the introduction of said impedance on either side of said axis of symmetry and the making of precision bearings by the use of said system is facilitated.

3. In a high frequency radio directional system emloying a symmetrical antenna system having a sharply directive characteristic, means for increasing the sharpness of bearing indications obtained by the pointing of said antenna system comprising a dielectric member, and means for alternately introducing said member between conductors of said antenna system on one side of its axis of symmetry and between corresponding conductors of said antenna system on the other side of its axis of symmetry, the length of the conductors affected in each case being between ¼ and ⅛ wave-length of the energy being radiated, whereby a relatively small change in the phase relation between the energy of the two halves of the antenna system is effected and the directional characteristic of said antenna system is shifted alternately from a position a few degrees on one side of the normal axis of said characteristic to a corresponding position on the other side of said normal axis without encountering substantial impedance unbalance or electrical contact resistance difficulties.

4. In a high frequency radio directional system, a symmetrical antenna system having a sharply directive response characteristic and phase changing means adapted to be non-conductively coupled alternately to corresponding points of said antenna system on opposite sides of the axis of symmetry thereof whereby the directive characteristic of said antenna system is alternately switched between a position a few degrees to one side of its normal axis to a like position a few degrees to the opposite side of its normal axis and the accuracy of the bearing obtained by pointing said antenna system at a source radiating or reflecting radio wave energy, can be substantially increased.

5. In a radio system, a multielement antenna system having electrical symmetry about a particular axis, identical transmission lines connecting the portions of said antenna system on opposite sides of said axis to a common junction, means for introducing at corresponding points of said transmission lines a particular discrete impedance which is alternately and non-conductively coupled with said two lines, the impedance alternately coupled with said two lines being substantially equal in magnitude to the characteristic impedance of the lines.

6. In a radio system, a multielement antenna system having electrical symmetry about a particular axis, identical transmission lines connecting the portions of said antenna system on opposite sides of said axis to a common junction, means for introducing at corresponding points of said transmission lines a particular discrete impedance which is alternately and non-conductively coupled with said two lines, the point on each of said lines to which said impedance is coupled being at a distance of substantially .18 wave-length from the common junction of said lines.

7. In a radio system, a multielement antenna system having electrical symmetry about a particularly axis, identical transmission lines connecting the portions of said antenna system on opposite sides of said axis to a common junction, means for introducing at corresponding points of said transmission lines a particular discrete impedance which is alternately and non-conductively coupled with said two lines, the impedance alternately coupled with said two lines being substantially equal in magnitude to the characteristic impedance of the lines and the point on each line to which said impedance is coupled being at a distance of substantially .18 wave-length from the common junction of said lines.

8. An antenna system for directive radio systems comprising a pluraltiy of antenna elements arranged in two like groups, the groups being symmetrically disposed about a common axis, a pair of substantially identical transmission line systems connecting said two groups of antenna elements to a common junction point, a capacitative device comprising a rotary element and two stator elements, the rotary element capacitatively engaging the two stator elements for alternate halves of each complete rotation, respectively, one stator being conductively connected across one of said transmission line systems, the other stator being conductively connected across the other of said transmission line systems the capacity between each stator and the rotor when fully engaged therewith being of the value corresponding to a reactive impedance of substantially the same magnitude as the characteristic impedance of the transmission line to which the stator is connected, whereby a predetermined electrical impedance can be alternately intro-

duced in shunt across first one and then the other of said transmission line systems by rotating said rotor element without making or breaking conductive connections to said lines and lobe-switching of said antenna system to enhance the accuracy of directive determinations dependent upon the directive properties of the antenna system is more satisfactorily effected.

9. The arrangement of claim 8, the connection of each stator to its respective line being such that the impedance appears effectively at an electrical distance of .18 wave-length of the energy employed, from the junction point of the two transmission line systems.

10. An antenna system for directive radio systems comprising a plurality of antenna elements arranged in a plurality of like groups, the groups being symmetrically disposed about a common axis, a transmission line system connecting each group of antenna elements to a common junction point, the respective transmission line systems being substantially identical, a capacitative device comprising a rotor element and a plurality of stator elements, one stator element being associated with and conductively connected across each of said transmission line systems, respectively, the capacity of each stator element when fully engaged by the rotor element being such that its impedance is substantially equal to the characteristic impedance of the transmission line system, the stator elements being regularly spaced and the rotor capacitatively engaging each stator for approximately half of each complete rotation whereby when the rotor is turned impedances are successively placed and removed from the transmission line systems in a regular rotative manner and lobe-switching of the directive beam of said antenna system is effected in several planes.

11. The antenna system of claim 10, the stator element for each transmission line system being effectively connected thereto at a distance which is electrically .18 wave-length of the energy employed from the common junction point of the line systems.

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The following references are of record in the file of this patent:

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