Aug. 24, 1965 F. V. SCHULTZ 3,202,995

STEERABLE CIRCULAR TRAVELING-WAVE ANTENNA

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6 Sheets-Sheet 1

FIG. 1.

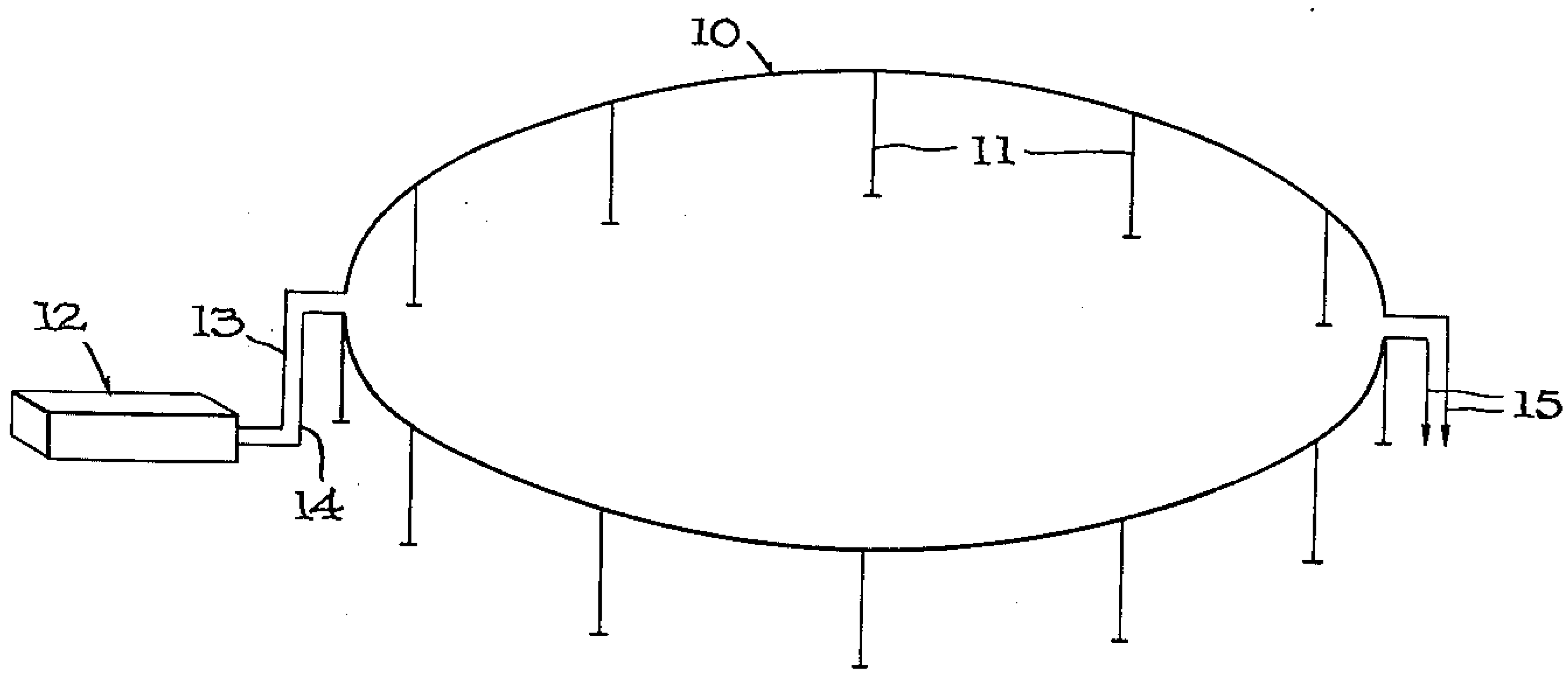

FIG. 2.

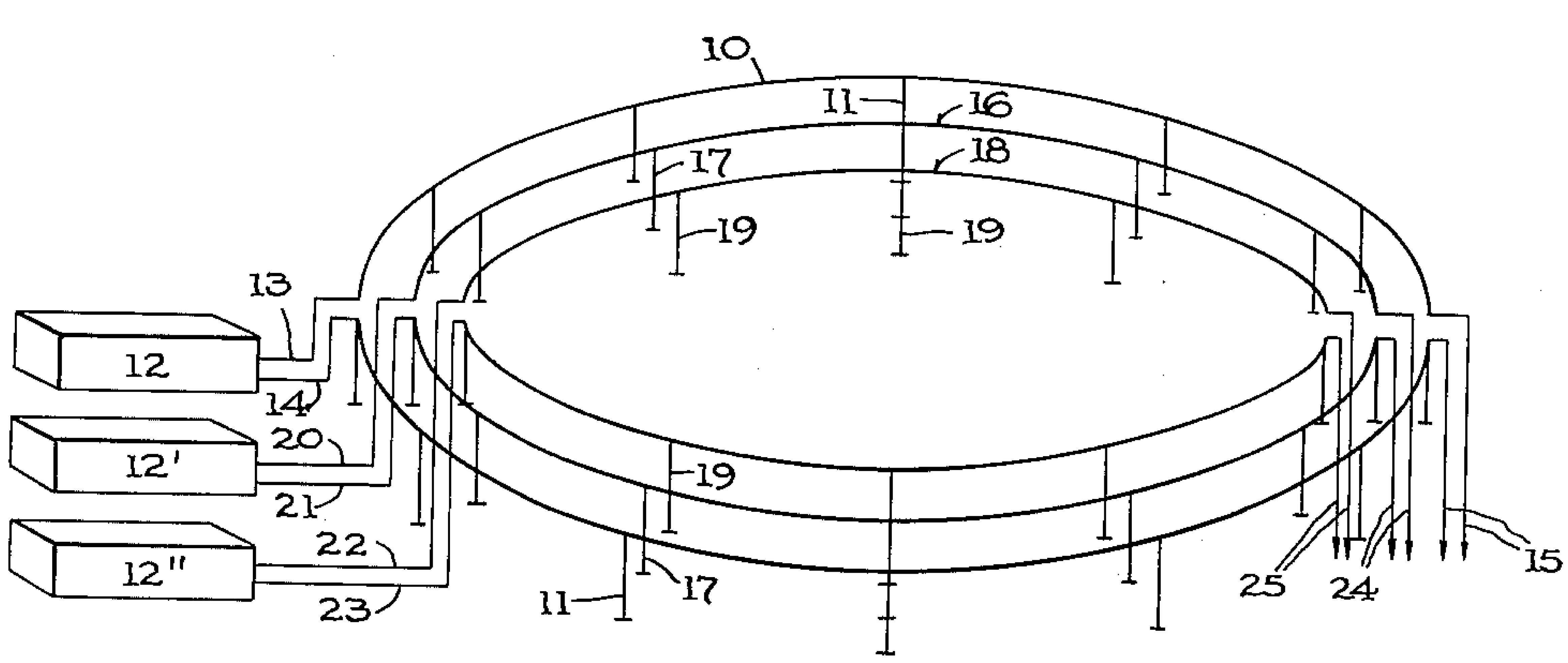

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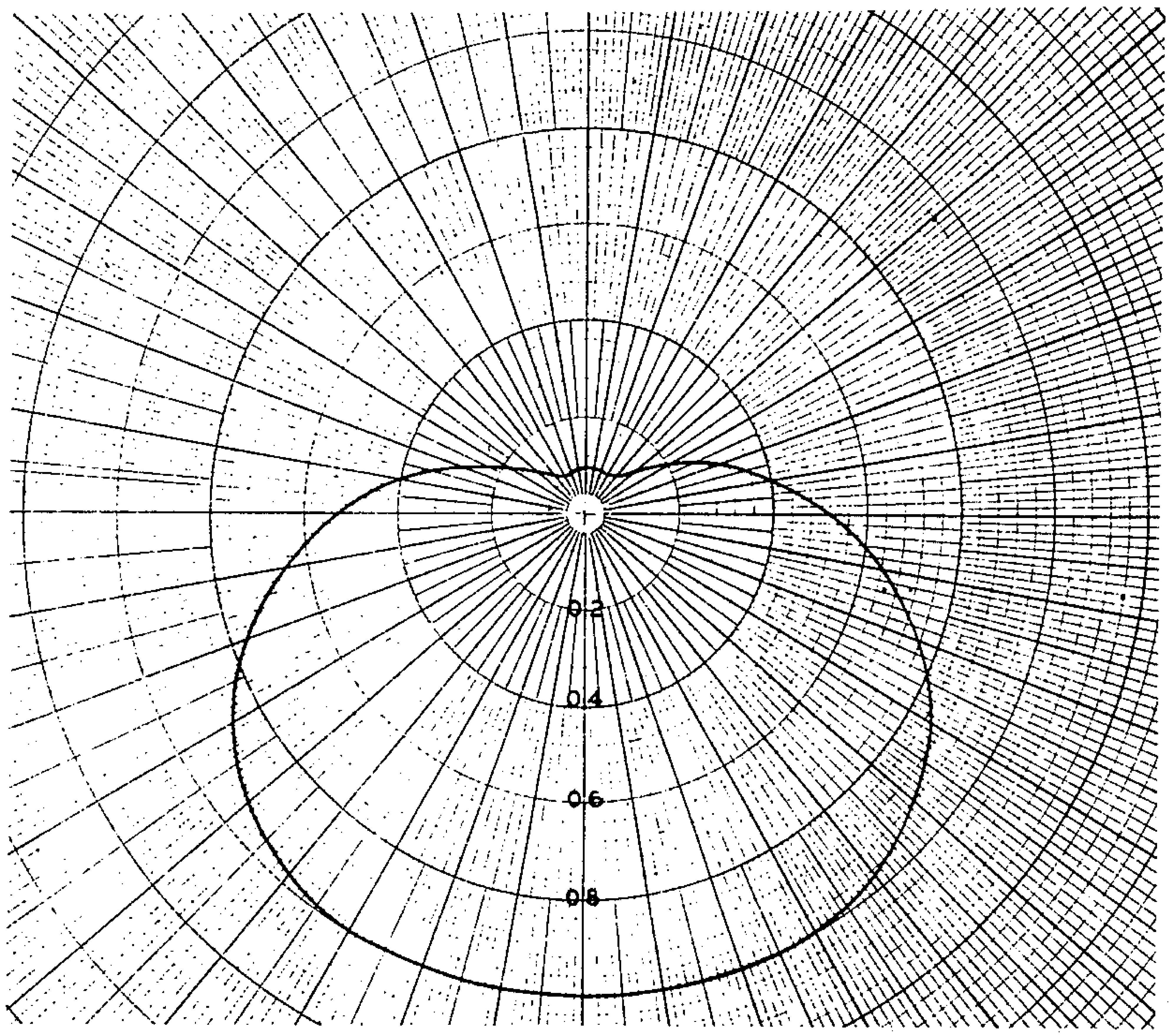
Fig. 3.



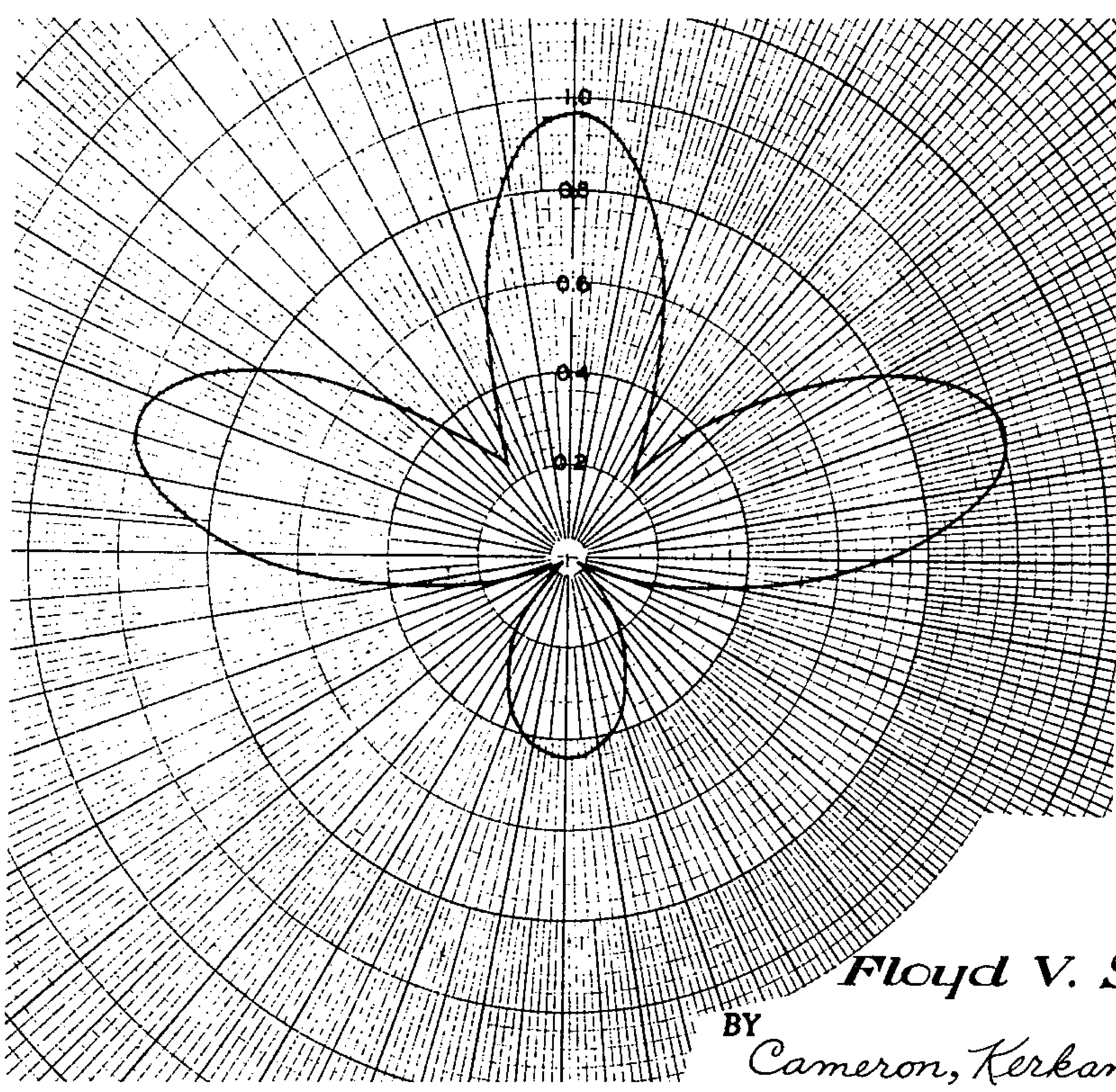


Fig. 4.

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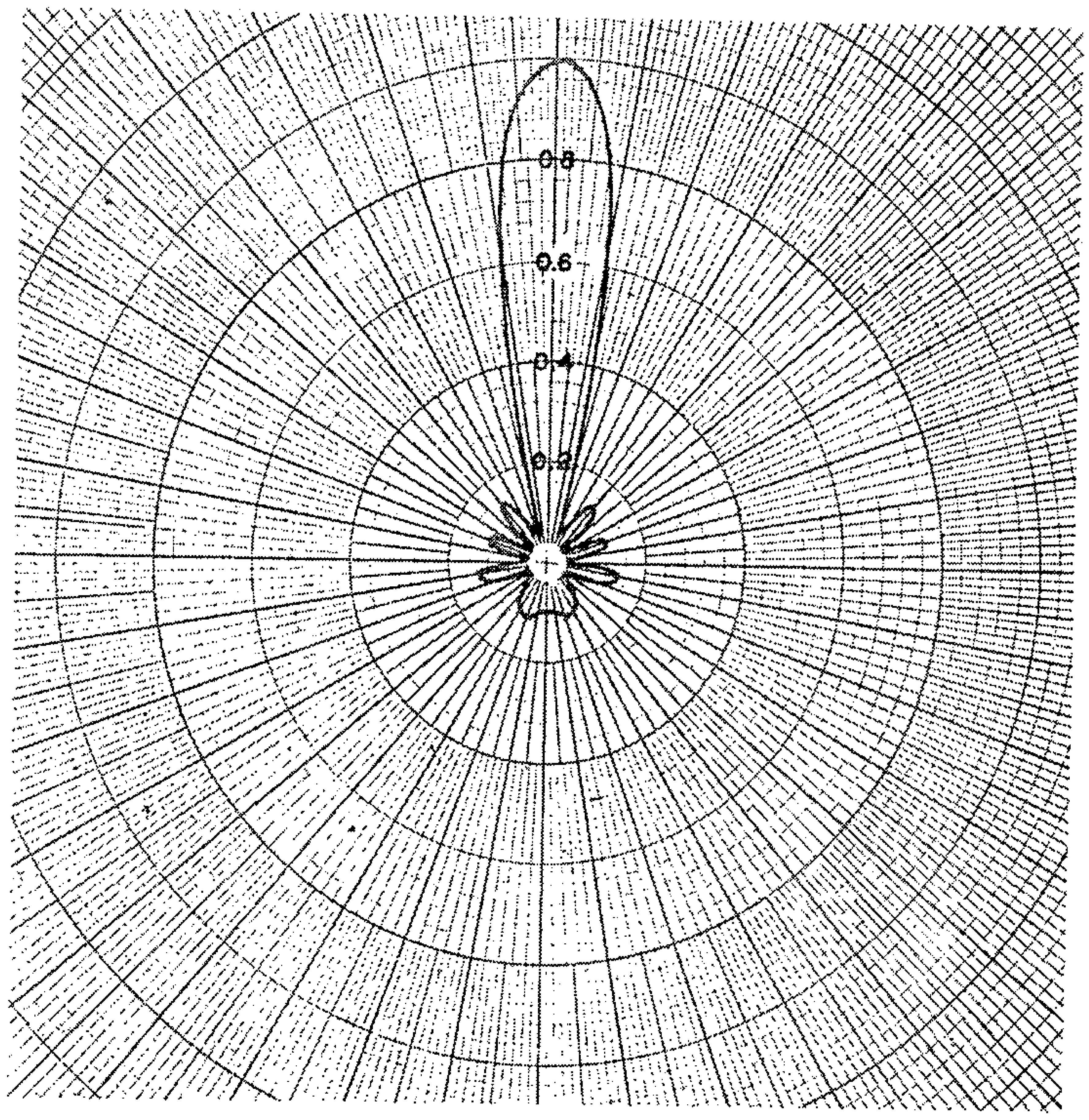

Fig. 5.

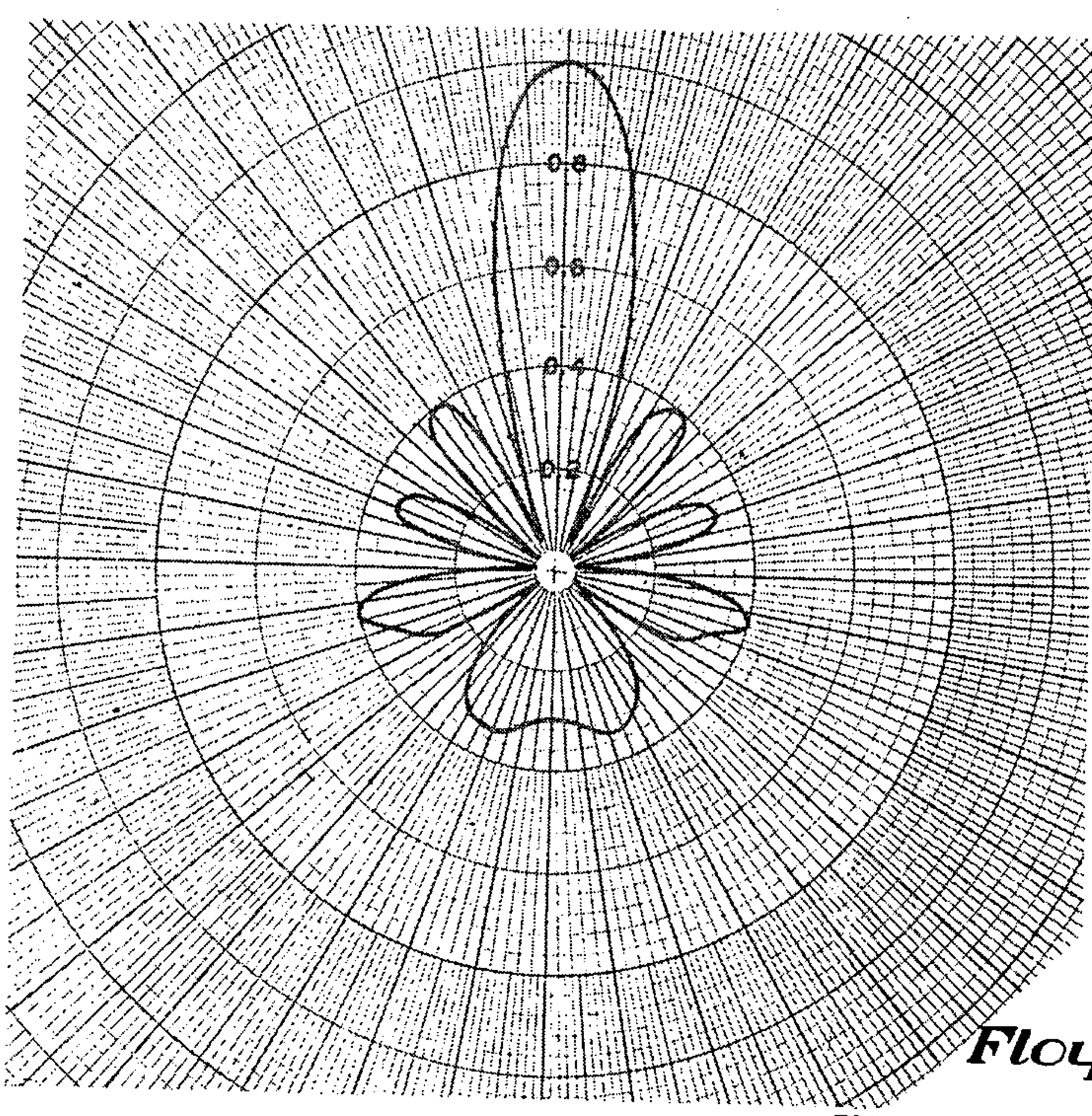

Fig. 6.

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FIG. 7.

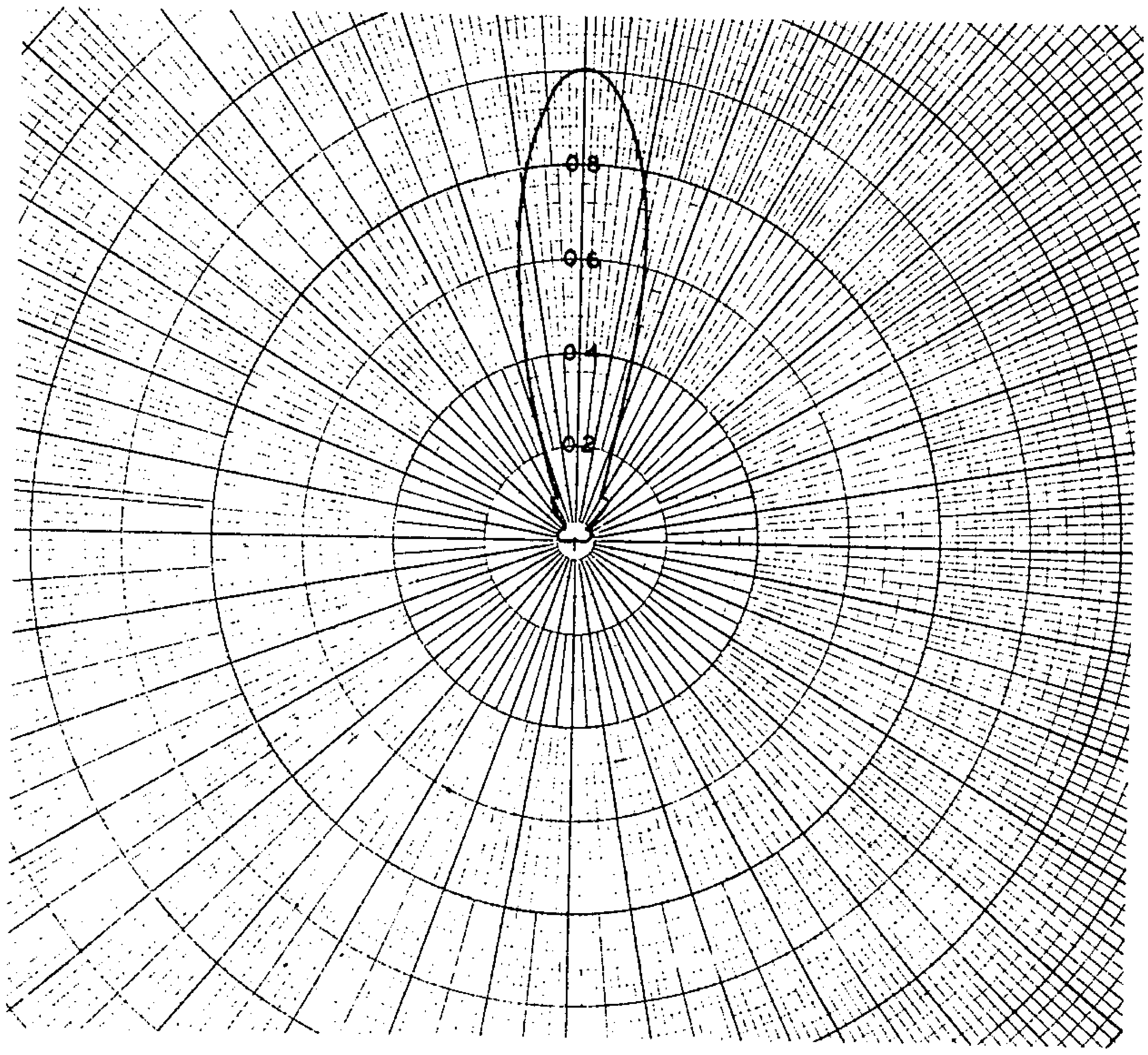

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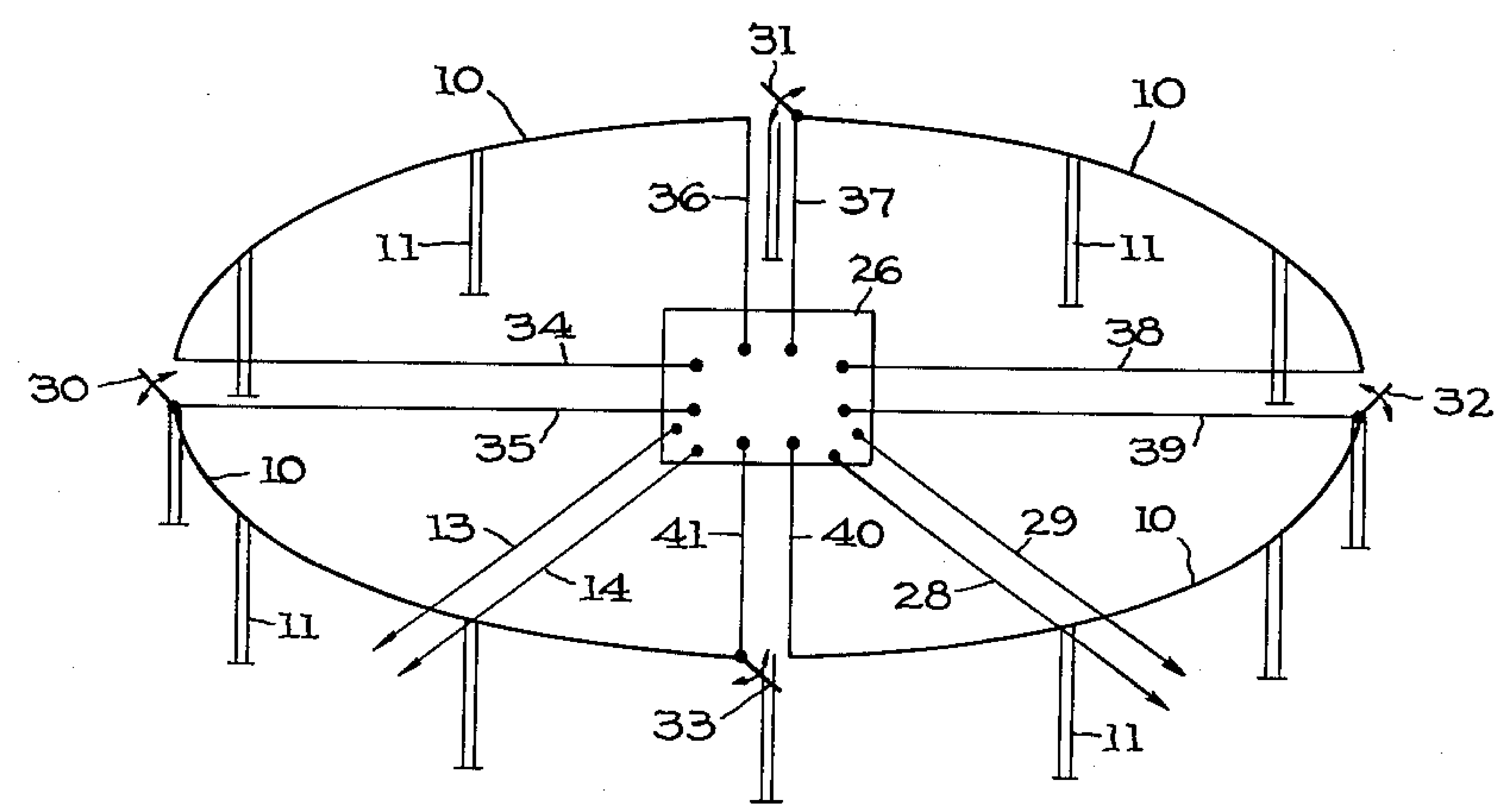
FIG. 8.



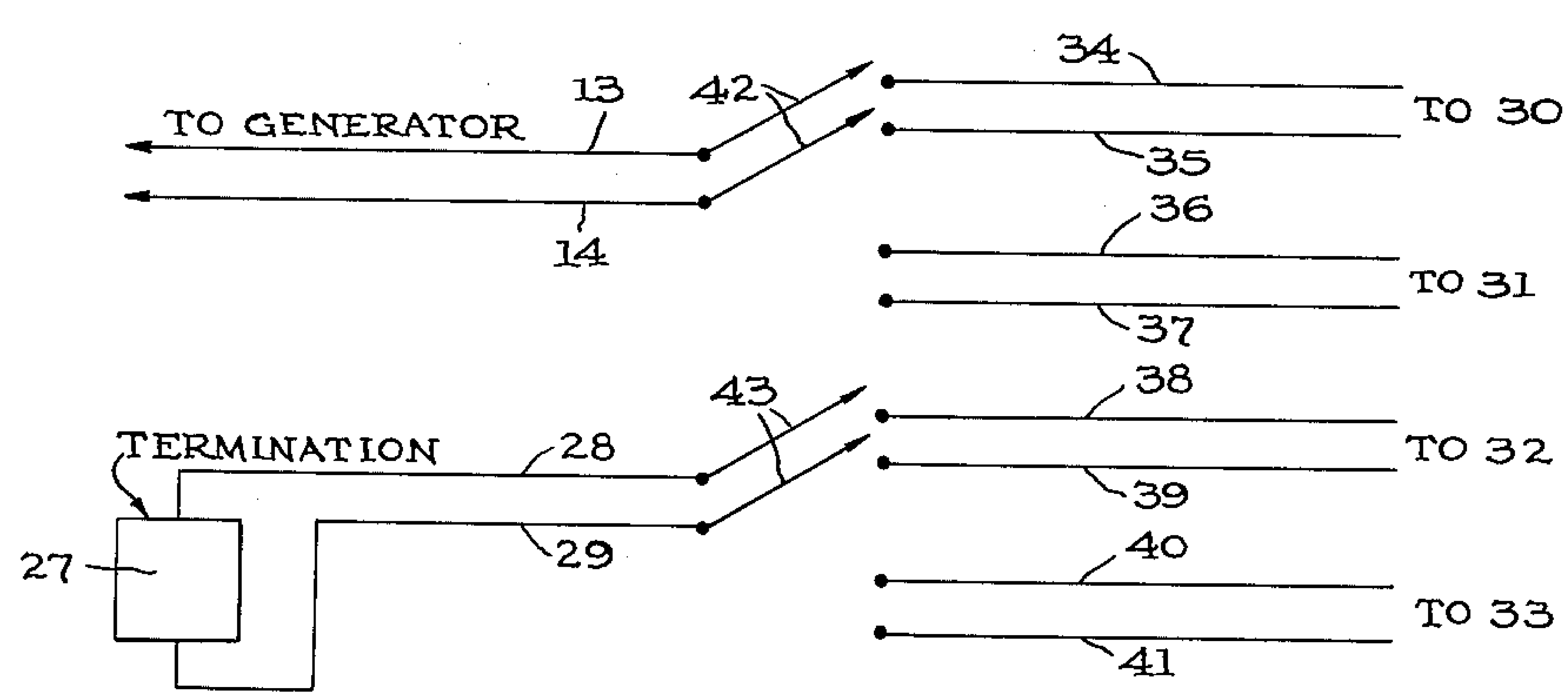


FIG. 9.

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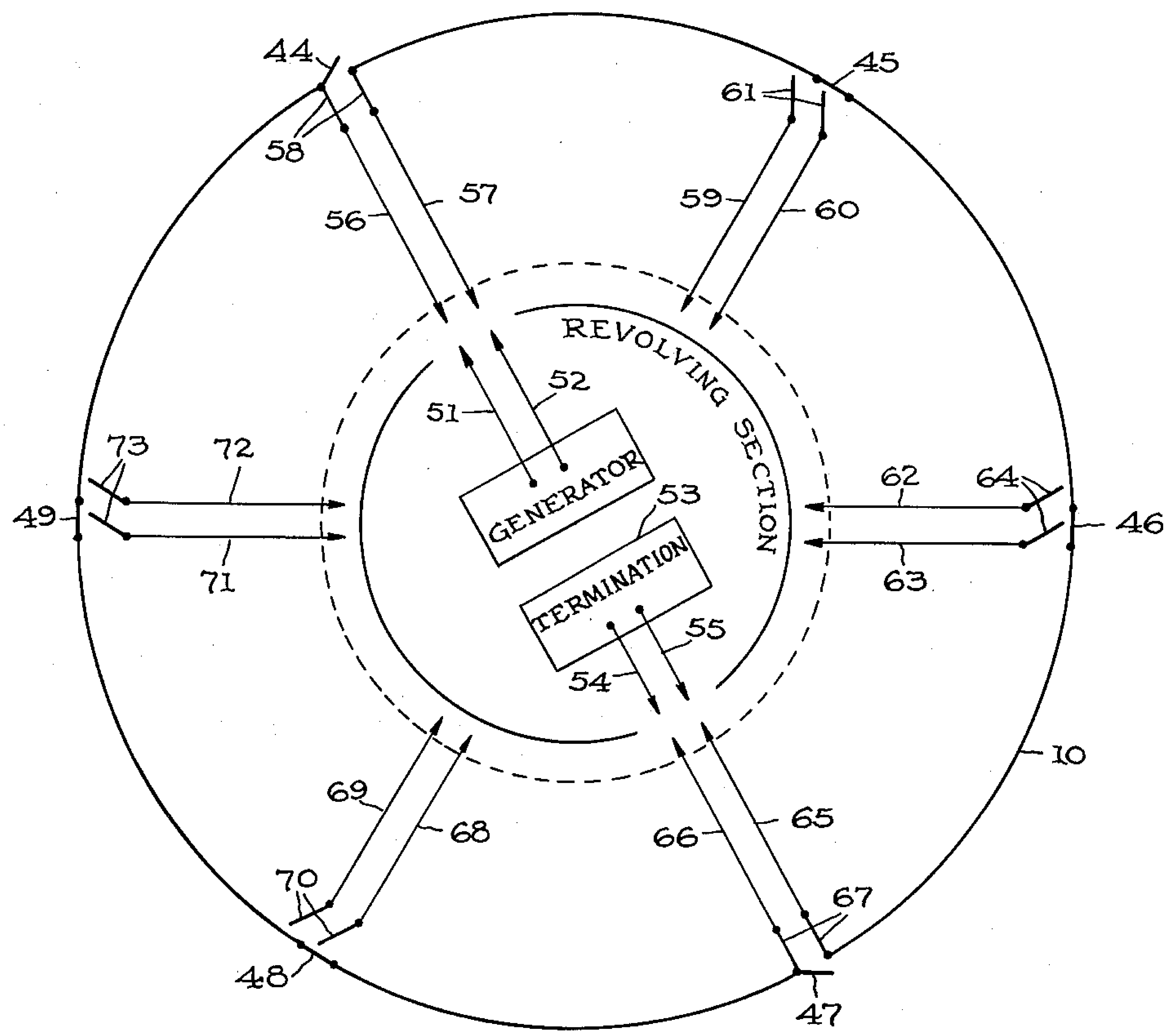

FIG. 10.

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United States Patent Office

3,202,995

Patented Aug. 24, 1965

3,202,995

STEERABLE CIRCULAR TRAVELING-WAVE ANTENNA

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Filed Mar. 3, 1961, Ser. No. 93,273
2 Claims. (Cl. 343—732)

This application is a continuation-in-part of application Serial No. 564,701, now abandoned, having the same title and filed February 10, 1956.

This invention relates to circular traveling-wave antennas and more particularly to such antennas in which a generator is connected at one point in the antenna and a suitable termination impedance is connected into the antenna at the diametrically opposite point so that the antenna radiates a main beam in the direction of the terminating impedance.

Most unexpectedly I have found that in a circular traveling-wave antenna of this type if the terminating impedance is such that no appreciable standing waves of current exist on the antenna conductor and if the circumference of the antenna has any value from above 3 wave lengths to about 7 wave lengths the antenna will radiate a main beam in the direction of the terminating impedance. I have found that with a single circular traveling-wave antenna of this type the levels of the side lobes are high but these side lobes can be reduced by using simultaneously two or more concentric circular traveling-wave antennas having different radii with the feed points of all antennas placed on the same radial. I have also found that such an antenna is operable over a wide band width of frequency and that the main beam may be directed in azimuth.

Azimuth direction of the main beam is obtained by moving the feed point and the load point around the circumference of the antenna.

It is accordingly an object of the present invention to provide novel circular traveling-wave antennas in which the main beam is radiated in the direction of the terminating impedance.

Another object is to provide such an antenna in which the side lobes of the main beam are reduced by the use of two or more circular traveling-wave antennas arranged concentrically in the same plane with different radii.

Another object is to provide such an antenna in which the azimuth of the main beam can be directed by moving the feed point and the terminating impedance around the circumference of the antenna.

Another object is to provide such antennas in which the circumference of the circular traveling-wave antenna may have any value from 3 to 7 wave lengths and in which the diameter thereof may vary from about 1 to 2.23 wave lengths.

Another object is to provide such antennas having their direction of maximum sensitivity toward the load end of the antennas.

Other and further objects of the present invention will appear from the following description of illustrative embodiments thereof.

Circular traveling-wave antennas in accordance with the present invention are capable of various mechanical embodiments and examples of the same are described hereinafter for purposes of illustration. Such illustrative embodiments of the present invention should in no way be construed as defining or limiting the same and reference should be had to the appended claims to determine the scope of this invention.

In the accompanying drawings, in which like reference characters indicate like parts, FIG. 1 shows an embodiment of the circular traveling-wave antenna of the present invention in which one circular antenna is fed at one side and is terminated at the diametrically opposite point by means of a load;

FIG. 2 is another illustrative embodiment of the circular traveling-wave antenna of the present invention in which three circular antennas are arranged concentrically and in the same plane with a different radii to reduce the side lobe levels of the main beam;

FIG. 3 is a normalized azimuthal radiation intensity diagram where $\Delta=15°$ (radiation intensity measured at an elevation angle above the horizontal of 15°) for a circular antenna of the prior art;

FIG. 4 is a normalized azimuthal radiation intensity diagram where $\Delta=15°$ for a circular traveling-wave antenna with a circumference of 2 wave lengths;

FIG. 5 is a normalized azimuthal radiation intensity diagram where $\Delta=15°$ of the circular traveling-wave antenna of FIG. 1 with a circumference of 5 wave lengths;

FIG. 6 is a diagram showing relative ϕ component of field strength at $\Delta=15°$ of the circular traveling-wave antenna of FIG. 1 with a circumference of 5 wave lengths;

FIG. 7 is a normalized azimuthal radiation intensity diagram at $\Delta=15°$ of the circular traveling-wave antenna of FIG. 2 in which the antennas have circumferences of 3, 4 and 5 wave lengths;

FIG. 8 shows a modification of the embodiment of FIG. 1 in which the feed and opposed termination can be selectively connected at four spaced points about the antenna for direction of the main beam in azimuth;

FIG. 9 is a schematic representation of suitable switching apparatus for use with the embodiment of FIG. 8; and

FIG. 10 shows another modification of the embodiment of FIG. 1 in which the feed and opposed termination can be selectively connected at six spaced points about the antenna for direction of the main beam in azimuth.

Circular antennas are known in the prior art and one such circular antenna is shown in U.S. Patent No. 2,247,743 granted to Howard H. Beverage, on July 1, 1941. The antenna of FIG. 1 of this patent is ½ wave length or less in diameter and has its direction of maximum sensitivity toward the receiver. In the present invention, on the other hand, in which the diameter of the circular antenna varies from the 1 to 2.23 wave lengths the direction of maximum sensitivity is toward the load end of the antenna.

The radiation intensity of an antenna following the Beverage concept is shown in FIG. 3 and is substantially shaped as a cardioid having a beam width, to the half-power points, of 180° while the beam width of the circular traveling-wave antenna of the present invention is about 30° at its frequency of optimum operation.

It will therefore be apparent that the circular traveling-wave antenna of the present invention provides advantages and results unobtained by antennas of the prior art.

Referring now to the several figures, in FIG. 1 the circular antenna is shown at **10** and is supported above the ground by suitable poles or towers **11**. Antenna **10** has a circumference of from about 3 wave lengths to about 7 wave lengths and a diameter of from about 1 to 2.23 wave lengths. Generator **12** is connected to antenna **10** by transmission lines **13** and **14**. Antenna **10** is terminated at a point diametrically opposite transmission lines **13** and **14** by a suitable load **15** which may be a lossy transmission line having a characteristic impedance of from approximately 700 to 800 ohms. If this antenna had a diameter of less than ½ wave length its normalized radiation intensity would be similar to that of the antenna of the Beverage patent as shown in FIG. 3. If antenna **10** has a circumference of 2 wave lengths its normalized radiation intensity is that shown in FIG. 4. From FIG. 4

it will be apparent that the radiation is scattered, more or less, in all directions and that the antenna therefore has little use where a sharply defined directed main beam is required.

However, when antenna 10 of FIG. 1 is given a circumference of from 3 to 7 wave lengths, say 5 wave lengths, in accordance with the present invention its normalized radiation intensity is that shown in FIG. 5. It will be readily apparent from inspection of FIG. 5 that the main beam of intensity is sharply defined and directed away from generator 12. It will be noted that the side lobes are low with minimum loss of intensity away from the main beam.

For some applications the ϕ-component of the electric field intensity may be of more interest than the normalized radiation intensity. When antenna 10 of FIG. 1 is given a circumference of 5 wave lengths, in accordance with the present invention, its normalized ϕ-component of electric field intensity is that shown in FIG. 6.

As noted above, when it is desired to reduce the side lobes of the main beam two or more circular antennas may be arranged in the same plane having a common center with varying radii and such an arrangement is shown in FIG. 2. In this embodiment of the present invention a second circular antenna 16, mounted upon poles or towers 17, is arranged in the same plane as antenna 10 and is of smaller diameter than antenna 10. Antenna 16 is connected to generator 12′ by transmission lines 20 and 21 which connect to the antenna on the same radius as transmission lines 13 and 14. A third circular antenna 18 is arranged in the same plane as antennas 10 and 16, is of smaller radius than antenna 16, and is carried by poles or towers 19. Antenna 18 is connected to generator 12″ by transmission lines 22 and 23 and transmission lines 22 and 23 connect to antenna 18 on the same radius as leads 13, 14, 20 and 21. Antenna 16 is provided with a suitable load 24 and antenna 18 is provided with a suitable load 25, loads 24 and 25 being connected to their respective antennas on the same radius as load 15 and diametrically opposite to the connection points for the transmission lines.

With this arrangement of circular antennas (FIG. 2), and assuming that antenna 10 has a circumference of 5 wave lengths, that antenna 16 has a circumference of 4 wave lengths, and that antenna 18 has a circumference of 3 wave lengths, the normalized radiation intensity of this embodiment of my circular traveling-wave antenna is shown in FIG. 7. In this figure it is seen that the main beam of radiation is sharply defined and directional in character with the side lobes reduced to a minimum. Comparing the main beam of intensity of the embodiment of FIG. 2, as shown in FIG. 7, with the intensity of the antenna of the Beverage patent as shown in FIG. 4 of that patent and as shown in FIG. 3 herein, the differences between the two antennas are readily apparent and the advantages of the circular traveling-wave antennas of the present invention are obvious.

The modified antenna and circuitry of FIGS. 8 and 9 provides for use of the antenna in four selective directions of azimuth of the main beam. Antenna 10 is provided with a central station 26 receiving generator leads 13 and 14. Station 26 contains termination 27 which has leads 28 and 29. Antenna 10 is broken at 90° intervals about its circumference and these breaks are closed by suitable switches 30, 31, 32 and 33. Leads 34 and 35 extend from station 26 to opposite poles of switch 30; leads 36 and 37 extend from station 26 to opposite poles of switch 31; leads 38 and 39 extend from station 26 to opposite poles of switch 32; and leads 40 and 41 extend from station 26 to opposite poles of switch 33.

As seen in FIG. 9, generator leads 13 and 14 connect to a double pole four throw switch 42 and termination leads 28 and 29 connect to a double pole four throw switch 43. The generator can thus be connected by switch 42 to any one selected pair of leads in any one of four directions spaced at 90° about the antenna and the termination 27 can then be connected by switch 27 to the appropriate pair of leads to that point in antenna 10 diametrically opposite to the generator connection. The appropriate pair of switches 30, 31, 32 and 33 to which the generator leads and the termination leads are connected will be opened and the remaining switches will be closed. As shown in FIG. 9, the generator is connected toward switch 30 so that the azimuth of the main beam is toward switch 30. Switch 30 will therefore be opened. The termination 27 is connected toward switch 32 diametrically opposite switch 30 and switch 32 will be opened. Switches 31 and 33 will be closed. If the generator is connected toward switch 31 then the termination will be connected toward switch 33; both switches 31 and 33 will be opened; and switches 30 and 32 will be closed, and so on for each of the four points of azimuth for the main beam.

FIG. 10 illustrates another embodiment of the present concept having six azimuth positions for the main beam spaced at 60° about the circumference of antenna 10. Antenna 10 is broken at 60° intervals and each break can be closed by an appropriate switch 44, 45, 46, 47, 48, 49, respectively. As in the embodiment of FIGS. 8 and 9 all switches in the circumference of antenna 10 are closed except those to which the generator and termination leads are connected. A central revolving station 50 includes the generator having leads 51 and 52 and the termination 53 having leads 54 and 55, leads 51 and 52 and leads 54 and 55 being in parallel lines parallel to the diameter of station 50. Rotation of station 10 permits selective engagement of the generator leads and the termination leads with leads to the circumference of the antenna now to be described. Leads 56 and 57 parallel to a radius of antenna 10 connect to a double pole single throw switch 58 which can be connected across switch 44; similar leads 59 and 60 connect to a single throw double pole switch 61 which can be connected across switch 45; similar leads 62 and 63 connect to similar switch 64 which can be connected across switch 46; similar leads 65 and 66 connect to similar switch 67 which can be connected across switch 47; similar leads 68 and 69 connect to similar switch 70; and similar leads 71 and 72 connect to similar switch 73 which can be connected across switch 49. Switches 58, 61, 64, 67, 70 and 73 are normally open and only that pair of these switches are closed which connect the leads in the desired azimuth of main beam generation and the corresponding diametrically opposite termination leads.

If main beam generation is desired in azimuth toward switch 44, station 50 is rotated until generator leads 51 and 52 engage and connect to leads 56 and 57, respectively, switch 58 is closed and switch 44 is opened. Termination leads 54 and 55 then engage and connect to leads 65 and 66, respectively, switch 67 is closed and switch 47 is opened. Switches 45, 46, 48 and 49 are closed and switches 61, 64, 70 and 73 are opened.

By appropriate rotation of station 50 generator leads 51 and 52 can be engaged with and connected to any selected pair of leads to the antenna 10; termination leads will be automatically engaged with and connected to the diametrically opposed pair of leads to antenna 10; and by appropriate switch actuation, as discussed above, main beam propagation in desired azimuth can be obtained, it being obvious that antenna 10 can be broken at any number of desired points with appropriate leads thereto to give as many directions in azimuth of main beam propagation as may be desired.

It should now be apparent to those skilled in the art that by the present invention I have provided a novel circular traveling-wave antenna which in every way satisfies the several objectives described above.

Changes in or modifications to the above described illustrative embodiments of my invention may now be suggested to those skilled in the art without departing from my inventive concept. Reference should therefore be had to the appended claims to determine the scope of this invention.

What is claimed is:

1. A traveling-wave antenna comprising a horizontal circular loop having a circumference of from approximately three to seven wave lengths, breaks in said antenna spaced at 90° about its circumference, switches normally connecting across said breaks, a central switching station, a pair of leads from said station for each of said breaks connected to opposite sides of its respective break, a pair of transmission leads to said station, a pair of termination impedance leads to said station, a double pole four throw switch connected at said station to said transmission leads and selectively connected to one of said pairs of leads, and a second double pole four throw switch connected at said station to said impedance leads and selectively connected to that one of said pairs of leads diametrically opposite to that pair engaged by said first switch, said switches being open at the breaks connected by said pairs of leads engaged by said switches whereby the main beam of radiation of said loop is directed away from that pair of leads engaged by said first switch.

2. A traveling-wave antenna comprising a horizontal circular loop having a circumference of from approximately three to seven wave lengths, a plurality of diametrically opposed breaks equally spaced in the circumference of

said loop, switches normally closing said breaks, a rotary switching station centrally disposed within said loop, a generator at said station, a termination impedance at said station, a pair of generator leads from said generator parallel to a radius of said loop, a pair of termination impedance leads from said termination impedance in the same diameter as and oppositely disposed to said generator leads, a pair of leads for and connected across each of said breaks and extending to said station for selective engagement by said generator and said impedance leads upon rotation of said station, said switches being open at said breaks connected by said pairs of leads engaged by said generator and said impedance leads whereby the main beam of radiation of said loop is directed away from that pair of leads engaged by said generator leads.

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HERMAN KARL SAALBACH, *Primary Examiner.*

GEORGE N. WESTBY, *Examiner.*

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,202,995 August 24, 1965

Floyd V. Schultz

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 24, for "above" read -- about --; column 2, line 46, for "the", first occurrence, read -- about --.

Signed and sealed this 5th day of April 1966.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents