DIRECTIVE BEAM ROTATING MEANS
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6 Claims. (Cl. 342—109)

My invention relates to directive beam rotating means and is particularly directed to electrical means, without inertia, for rotating or scanning through any angle, including 360 degrees, a high frequency radio beam.

In such applications for micro-wave transmitters as beacons or radar, it is often desirable to swing a directional beam through all or part of a circle, and the usual means herefore use comprise an antenna and reflector mounted on a rotatable shaft. The mechanical problems are obvious of properly balancing the rather bulky antenna equipment for free rotation particularly at high speeds.

Among the objects of my invention is a system for rotating about a fixed point a directional radio beam solely by electrical means. That is, the object of my invention is a system for rotating a beam without moving mechanical parts.

In accordance with my invention, an envelope, containing an atmosphere of electrons, is placed in front of a directional antenna. The density of electrons, which is a function of the index of refraction or deviation of high frequency radio waves in the electron atmosphere, is progressively and if desired rhythmically changed to sweep the beam through a predetermined angle. A plurality of such envelopes may be arranged about the antenna, each envelope being placed to receive the waves which are deflected through a predetermined angle, usually the greatest angle, by the preceding adjacent envelope so that the radiation beam may be deflected at any desired speed through 360 degrees.

The above-mentioned and other features and objects of my invention and the manner of attaining them will become more apparent and the invention itself will be best understood, by reference to the following description of embodiments of my invention taken in conjunction with the accompanying drawing, wherein:

FIGURE 1 shows, in plan, one arrangement of transmitter and antenna of my invention;
FIGURE 2 shows graphically the relation of index of refraction and electron density of a prism of my invention;
FIGURES 3 and 4 show, in plan, other arrangements of transmitter and antenna of my invention;
FIGURE 5 shows graphs of voltages and other functions of the antenna of FIGURE 4; and
FIGURE 6 is a block diagram of the circuits of one embodiment of my invention.

The purpose of deflecting a radio beam, I employ the refracting properties of an atmosphere of electrons, and by varying the electron density the deflection of the beam is controlled without the aid of mechanically movable parts. With inertial electrical controls of my invention the speeds of scanning may far exceed the speeds attainable by mechanical means. While high electron densities may be obtained in vacuum by various means, electrons produced by ionized gas will be first considered.

In FIGURE 1 is shown a generator 1 connected to a directional antenna. The generator contemplates is adapted for generating centimeter waves, such as those employed in beacon service, radar, and the like. The output of the generator is fed to the dipole, probe, or loop 2 at the focal center of a parabolic reflector 3 of conventional type. In my device, however, the coupling wave guide or coaxial cable between the antenna and generator requires no rotating joint of the type usually used for rotating antennae, and hence obviates the discontinuity and impedance matching problems of the rotating joint.

Extending across and directly in front of the directional antenna, to intercept substantially all of the energy of the radiated beam is placed an electron refracting device. This device comprises a hermetically sealed envelope 4 in which an atmosphere of electrons may be established, and to the electron density being sufficient, for the particular frequency of radiation from the antenna, to change the direction of the beam. The requisite electron density may be obtained by ionizing an inert gas, such as neon or argon, in the envelope. The envelope walls are transparent to the radiated energy and are preferably of low-loss material, such as some of the hard glasses. Two sides 5 and 6 of the envelope are planar and are at an angle A determined by such factors as the maximum deflection desired, frequency, and electron density. The sides 5 and 6 are smooth, uniform in thickness and composition, and otherwise homogeneous to the transmission of high frequency energy. Two spaced electrodes 7 and 8 are provided in the envelope for ionizing the gas. One electrode may if desired be electron emissive, either hot or cold.

According to an important feature of my invention, the voltage between the ionizing electrodes in the prism is varied in accordance with the desired rate and angle of deflection.

It is generally agreed that the index of refraction, u, of an ionized medium, when magnetic effects and energy losses are negligible, is

\[ n = \sqrt{1 - \frac{4\pi e^2 N}{m u^2}} \]

where

- \( e \) = electron charge, esu.
- \( m \) = electron mass, grams
- \( w/2\pi = \) frequency
- \( N \) = number of electrons per cubic centimeter.

Since \( e \) and \( m \) are constants and for a given frequency, the index of refraction is a function only of electron density, \( N \). It is entirely feasible to obtain electron densities of the order \( 10^4 \) electrons per cubic centimeter which according to calculations are required for appreciable refraction of centimeter waves. In FIGURE 2 is shown graphically the functional relation 1 have found between electron density \( N \) and total angle of deflection \( D \) of 3 centimeter waves passing through a prism envelope having an angle \( A \) of 100 degrees. An angle of incidence, \( i \), of 25 degrees was arbitrarily chosen. The angle of incidence may of course be any finite value less than the so-called critical angle at which total reflection occurs from the surface boundary of the glass or ionized media.

At an electron density of \( 1.03 \times 10^4 \), the total angle of deflection is found to be 68 degrees. Hence, with the parameters mentioned the beam of electromagnetic energy radiated by the stationary antenna assembly 2-3 may be shifted slowly or rapidly through 68° merely by varying the potential between the ionizing electrodes. The beam of radio energy passed by the prism is bent only and is not diffused, scattered or distorted. It is concentrated that the side walls 5 and 6 of the prism be ground and polished, or precision cast, or otherwise fabricated to the optical fineness consistent with the manufacture and cost of devices of this size and type.

The ionizing potential on each prism may be varied manually or automatically. In FIGURE 1 a simple potentiometer 9 across a steady high potential source 10 may suffice for establishing the necessary range of elec-
tron densities and the range of beam deflection. The position of the potentiometer slide may be calibrated in angular degrees.

Alternatively, the electron density and beam deflection may be rhythmically varied as suggested in FIGURE 3. The generator 11 connected across the ionizing electrodes 7 and 8 may be designed to produce an undulating output of any desired wave shape, although for linear time-deflection a saw-tooth type wave is preferred.

To extend the deflection angle of the radiated beam, a second prism is positioned to receive the beam from the first prism, the position being selected so that only the beam at maximum deflection by the first prism, will impinge upon the second. It becomes apparent now that a plurality of prisms may be arrayed to produce a total of 360 degrees deflection. By successively varying the ionizing potentials of the several prisms, the beam may be made to rotate smoothly through a complete circle. There is no important limitation to the speed at which the beam of my invention may be rotated. The ionization and deionization time of the particular gas used in the prism envelopes would of course be considered only at very high speeds.

I propose in FIGURE 4 to so place a second gas filled prism 4' as to receive the beam of maximum deflection from the first prism 4. This feature extended comprises an array of three, four or more prisms, 4, 4', 4", etc., serially disposed in the curved path of the beam, each prism being so placed as to direct its beam of maximum deflection to the next succeeding prism. Where the maximum deflection per prism is less than 90 degrees, more than 4 prisms must of course be used for complete 360° rotation.

In a 360° cycle of operation, it is merely necessary to successively increase the electron density in each prism and hold the electron concentration at its fixed maximum value until the end of the cycle. In FIGURE 4, for example, separate saw-tooth generators, 11, 12, 13, 14, etc., are respectively connected to the electrodes of each prism. Conventional generators are contemplated, of any type which may be triggered by a control voltage of a predetermined value. Then, by selecting the control voltage at successively different values for the series of generators, the sequence of operation of the generators may be easily controlled by the master saw-tooth generator 15.

In FIGURE 5 is shown the time relations of the master control wave 15' of generator 15 and the output wave forms 11', 12', 13' and 14' of the generators 11, 12, 13, and 14. The ascending voltages applied to the prisms are successive and end-to-end for smooth, steady deflection of the beam throughout the cycle of rotation.

Where greater power outputs are required than can be delivered continuously by the equipment available, a pulse generator may be coupled to key the radio frequency generator for producing pulses of radio frequency energy, as well known in the art. In FIGURE 6, the high frequency generator 1 is turned abruptly on and off by the keyer 16, which is controlled by the pulse generator 17. The output of the pulse generator is also applied to the ionizing electrodes of the gas prism through the modulator 18. The function of the modulator and the pulse generator is to increase step-by-step the ionizing potential, and because the keyer is connected to the pulse generator, the radio frequency pulses and the steps in ionizing the voltage are synchronized.

While ionized gas as a source of electrons has been considered throughout this description, other methods of establishing the necessary electron density may be employed within the scope of my invention. High concentrations of electrons with relatively small inter-electrode current may be made in vacuum, for example, by operat-

ing a magnetron below cutoff so that the spiralling electrons continue in substantially fixed circles about the cathode. Again, in a reflex type velocity modulator, a cloud of electrons may be established in front of the reflection electrode with negligible current flowing to the electrode.

While I have described above the principles of my invention in connection with specific apparatus and circuits, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of my invention.

I claim:

1. In combination, a directional antenna, a plurality of prismatic envelopes each containing a wave-deflecting gaseous atmosphere, a first of said envelopes in the path of propagation of said antenna, a second of said envelopes placed to receive waves which are deflected through a predetermined angle by said first envelope, and means for successively ionizing said gaseous atmosphere in said envelopes.

2. In combination, a plurality of prismatic envelopes, each envelope containing spaced electrodes and an ionizable gas, a first of said envelopes being placed to receive and deflect wave energy, a second of said envelopes placed to receive said wave energy which is deflected through a predetermined angle by said first envelope, a voltage source, and means successively applying the voltage of said source to the electrodes of said envelopes.

3. In combination, a plurality of prismatic envelopes, each envelope containing spaced electrodes and an ionizable gas, each envelope being placed to receive wave energy received and deflected through a predetermined angle by an immediately adjacent envelope, and means to sequentially vary voltages between electrodes of said envelopes through predetermined ranges of ionizing potentials.

4. A system for producing an angular sweep of a radio beam, comprising a relatively fixed directive antenna, a first refracting prism comprising a gas-filled container mounted in the path of radiation of said antenna, an ionizing voltage source coupled to said container to vary ionization of said gas to sweep the beam through a given angle, a second similar refracting prism in the path of the beam substantially at one of its extremes of deflection, a second ionizing voltage source coupled to said second refracting prism to sweep the beam through a further angle, and means controlling said voltage sources to render them successively effective.

5. A system according to claim 4 further comprising other similar refracting prisms each successively mounted to receive energy from the preceding prism, said plurality being equal to the number needed to produce a full circular deflection of said beam, each of said further prisms being provided with a corresponding ionization voltage source.

6. A system according to claim 5, wherein each ionization voltage source comprises a saw-tooth generator, said controlling means comprising a synchronizing distributor for said generators.

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