May 20, 1952 J. H. GARDNER 2,597,313

ANTENNA

Filed June 7, 1945

FIG. 1

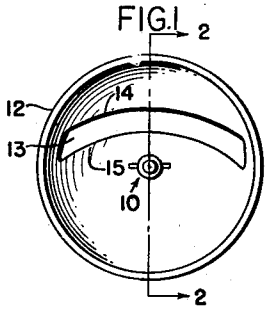


FIG. 2

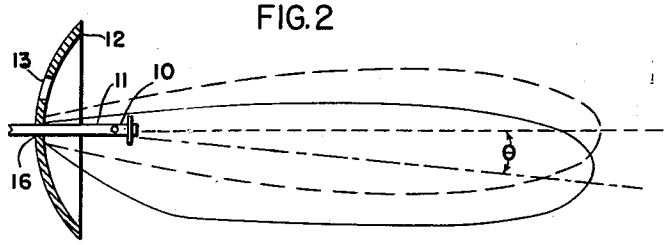


FIG. 4

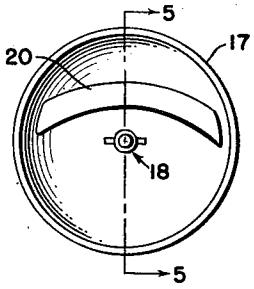


FIG. 5

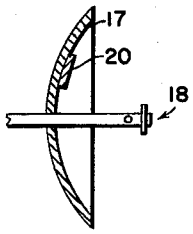


FIG. 6

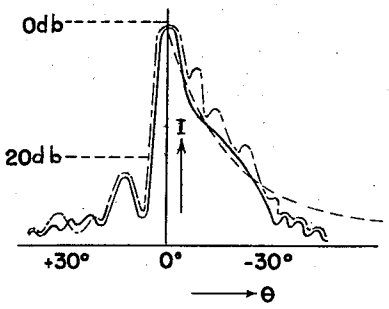
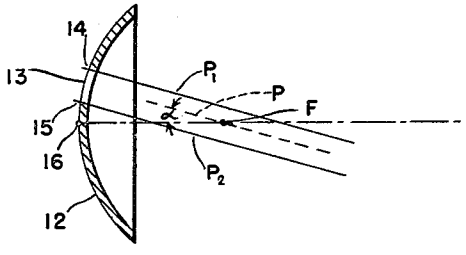


FIG. 3



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ANTENNA

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Application June 7, 1945, Serial No. 598,153

11 Claims. (Cl. 250—33.65)

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This invention relates to antennas for high frequency communication systems and particularly to radiating means for obtaining an energy distribution pattern closely approximating the relationship $\csc^2 \theta$ in one plane, generally a vertical plane, where θ is an angle measured from the axis of the radiating means.

In certain radio object-locating systems, for example, it is desirable that the distribution of energy in a vertical plane throughout a relatively wide angular range be such that the variation of energy density versus the radiation angle is a cosecant-squared function. This distribution provides generally uniform echo strength for targets disposed at substantially equal elevations with respect to the antenna, regardless of whether the target is distant or close in, and it eliminates, to a great degree, the need for tilting the antenna to obtain satisfactory coverage of the area under observation.

One means of achieving the desired radiation pattern as above described is disclosed in my copending application Serial No. 584,228 filed March 22, 1945, and issued on June 20, 1950 as Patent No. 2,512,147. In this copending application I have provided a modified paraboloidal reflector in which an elongated strip of metal is mounted in front of a portion of the reflector surface, said strip being inclined at an angle to a horizontal plane through the reflector axis.

I have found herein that an excellent $\csc^2 \theta$ radiation pattern may be produced by removing a strip of a paraboloidal reflector corresponding generally with the dimensions of a shadow which would be cast on the paraboloidal reflector surface by the strip of my above-mentioned application when illuminated from a source corresponding to the focal point of the paraboloidal reflector.

Accordingly one of the objects of the present invention is to provide a $\csc^2 \theta$ radiation pattern by simple modification of a paraboloidal reflector.

Another object of the invention is to provide a paraboloidal reflector having means for shaping a beam of radiant energy by subtracting energy from portions of the beam.

Still another object of this invention is to provide a parabolic reflector such as one shaped as a paraboloid of revolution in which a section of the surface thereof is removed. As an alternative construction, the removed section may be replaced by an absorbing or non-reflecting material, whereby a beam pattern of modified shape is produced.

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Other objects and advantages of the invention will become apparent as the description proceeds.

In the drawings:

Fig. 1 is a front elevation view of an antenna showing one embodiment of the reflector according to the invention.

Fig. 2 is a side sectional view of the same along the line 2—2 of Fig. 1;

Fig. 3 is a diagrammatic side sectional view of the reflector of Figs. 1 and 2 illustrating one means of determining the location of the modified portion according to the invention;

Fig. 4 is a front elevation view of an antenna illustrating another embodiment of the invention;

Fig. 5 is a side view of the antenna along the line 5—5 of Fig. 4; and

Fig. 6 is a diagram illustrating in rectangular coordinates the directive vertical patterns obtained with an antenna according to the present invention.

Referring to Figs. 1 and 2 of the drawing, a radiating element or source 10, such as a dipole and parasitic element, fed by a wave guide or coaxial line 11 is constructed and located in a conventional manner for illuminating a reflector 12. Reflector 12 is formed preferably as a paraboloidal surface having its focal point near the apparent center of the radiating source 10. As is well known, the reflector 12, as thus far described, is adapted to reflect radiant energy in a pencil type beam characteristically having a distribution pattern relativaly narrow both in elevation and azimuth as indicated in the dotted line configuration of Fig. 2.

According to this invention, reflector 12 is modified to obtain a distribution pattern which approximates a $\csc^2 \theta$ configuration in one plane, which for the present description may be considered the vertical plane of elevation. This is accomplished, according to one embodiment of the present invention, by removing a portion of the reflecting surface of reflector 12 such as by cutting out a strip or portion of the surface of suitable size and dimension to obtain the desired pattern.

In Fig. 1 the open portion or slot designated 13, which is formed when the surface portion is removed, is substantially quadrilateral in shape and extends substantially the full width of the paraboloidal reflector 12. Open portion or slot 13 may be disposed in the upper portion of reflector 12 (as shown) or in the lower portion, depending upon whether the $\csc^2 \theta$ configuration of

the pattern is desired at the bottom or top of the beam.

The open portion or slot 13 generally conforms in size and position to a shadow which would be cast upon the reflecting surface of reflector 12 by the strip member of my above-mentioned copending application. The exact dimensions and position of open portion 13 for obtaining a desired radiation pattern may be determined experimentally for various sized reflectors.

One manner for determining the position and definition of open portion or slot 13 involves passing a plane P (Fig. 3) through the focal point or center of the radiating source 10 as at F at an angle α which may preferably be between 5° and 20°, with the reflector axis. Planes P_1 and P_2, parallel to and equidistant from plane P, are extended to intersect the reflecting surface of reflector 12. The lines of intersection of planes P_1 and P_2 with the reflecting surface define the upper and lower limits or edges 14 and 15 of open portion or slot 13. The edges 14 and 15 are preferably spaced apart by a distance of more than a wave length of the energy directed on reflector 12 by radiating source 10. The distance between lower edge 15 and the vertex 16 of reflector 12 is determined by the particular pattern desired and depends to a certain extent on the size of reflector 12. It has been found that, for a 30"x (F=10.6") circular paraboloidal reflector 12, where F is the focal length of said reflector an excellent radiation pattern which closely approximates a $\csc^2 \theta$ pattern is obtained when the distance between lower edge 15 and vertex 16 is between two and three inches. A diagram showing an approximation of the radiation pattern in rectangular coordinates obtained by such a reflector is shown in a solid line in Fig. 6, the ideal cosecant curve being indicated in dotted lines.

The effect of the open portion or slot 13 on the radiation pattern normally produced by a full paraboloidal reflector 12, is believed to be due to the fact that the upper portion of the beam pattern, which would normally be produced if the open portion or slot 13 were not present, is removed to a certain extent from the radiation pattern, thus leaving the lower portion of the pattern. In other words, a subtraction effect on the beam pattern is produced by removal or subtraction of a portion of the reflecting surface of reflector 12.

It would appear that, with a reflector having an open portion 13 (or an absorbing portion as described hereinafter), an appreciable amount of the radiant energy from the source 10 would be lost. However, tests made of antennas embodying reflectors according to this invention indicate that much less energy is lost than would be expected, and in fact such tests show a satisfactory amount of relative gain with reflectors constructed in accordance with this invention.

Figs. 4 and 5 illustrate another embodiment of this invention. A paraboloidal reflector 17 is illuminated by a radiating source 18 in the manner described with reference to Figs. 1 and 2. Instead of removing a strip from reflector 12 to afford an open portion 13 as described hereinabove, a strip 20 of absorbing or electrically resistive material corresponding generally to the shape and size of open portion or slot 13 is disposed on the front surface of reflector 17 in the position of slot 13. According to a modification, absorbing strip 20 may be so disposed that it would replace the strip which is removed to afford open portion or slot 13.

Absorbing strip 20 may be of any suitable material which will not effectively reflect the radiant energy from source 18. Accordingly, strip 20 may comprise a sheet of suitable insulating material which may be a plastic such, for example, as phenolic resin or a phenol fibre coated on the face toward the source 18 with one or more layers of resistive material. The resistive material may for example be a mixture of finely divided graphite and a suitable binder spread on to the surface of strip 20 in one or more coats. Preferably the plastic sheet has a thickness of about

$$\frac{\lambda k}{4}$$

λk being the wave length of radiant energy passing through the particular plastic, of dielectric constant k, which is used.

The effect of the absorbing strip 20 is generally the same as that of open portion or slot 13. A radiation pattern in rectangular coordinates obtained with a reflector of the same characteristics as referred to with reference to Figs. 1 and 2 is illustrated in dotted and dashed lines in Fig. 6.

While preferred embodiments of this invention have been illustrated and described, it is to be understood that various other modifications and improvements may be made within the scope of the invention. Hence it is not desired that the invention be limited to the precise details set forth.

What is claimed is:

1. An antenna comprising a radiating means and a reflector, said reflector being shaped as a paraboloidal surface normally adapted to direct radiant energy in a pencil type beam along a main path, said reflector having a non-reflecting portion in its reflecting surface comprising an opening therein, said opening being generally quadrilateral in shape and extending horizontally substantially the full distance across one of the upper or lower halves of said reflector, the surfaces defining the upper and lower limits of said opening being the intersections with said reflecting surface of two parallel planes spaced equidistant on opposite sides of and parallel with a plane through the focal point of said reflector and disposed at an angle with the reflector axis, said opening being effective to modify the pattern of reflector by said reflection whereby an unsymmetrical radiation pattern is produced.

2. An antenna as claimed in claim 1 wherein the distance between said upper and lower limits of said opening is more than a wavelength of the radiant energy.

3. An antenna comprising a radiating means and a reflector, said reflector being shaped as a paraboloidal surface normally adapted to reflect radiant energy in a pencil type beam along a main path, non-reflective material positioned effectively to form a portion of the reflecting surface of said reflector, said non-reflective material being generally quadrilateral in shape and extending substantially the full distance across said reflector, the long edges of said portion lying along lines of intersection with said reflecting surface of two parallel planes spaced equidistant on opposite sides of, and parallel to, a plane through the focal point of said reflector and disposed at an angle to the reflector axis, said portion being effective to modify the reflective characteristics of said reflector whereby a differently shaped energy distribution pattern is produced.

4. An antenna as claimed in claim 3 wherein the non-reflective material comprises a strip of energy absorbing material, the width of said strip being more than a wavelength of the radiant energy.

5. An antenna comprising means for radiating electromagnetic wave energy, a directive reflector having an axis and positioned to reflect radiation from said radiating means in a given radiation pattern, and means for modifying said given radiation pattern in a predetermined manner including a substantially non-reflective portion within the boundaries of said reflector and positioned effectively to form a part of the surface of said directive reflector, said non-reflective portion extending substantially the full distance across said reflector on one side of said axis, the size and position of said non-reflective portion being determined by said predetermined manner of modification of said given radiation pattern.

6. An antenna according to claim 5 wherein said non-reflective portion is formed by an aperture in said reflector.

7. An antenna according to claim 5 wherein said non-reflective portion comprises electromagnetic wave energy absorbing material mounted on the surface of said reflector.

8. An antenna with means for distorting the normal directive radiation pattern approximately into a $\csc^2 \theta$ pattern in one plane where θ is the angle measured from the axis of directivity of said normal pattern comprising means for radiating electromagnetic wave energy, a paraboloidal reflector positioned to reflect radiation from said radiating means in a given radiation pattern, and means for distorting said given pattern approximately into the $\csc^2 \theta$ pattern in one plane including an elongated substantially non-reflective portion within the boundaries of said reflector and positioned effectively to form a part of the surface of said paraboloidal reflector, said non-reflective portion extending substantially the full distance across said reflector on one side of the axis thereof, said non-reflective portion being oriented substantially in a plane perpendicular to said one plane.

9. An antenna according to claim 8 wherein said non-reflective portion is formed by an elongated slot in said paraboloidal reflector.

10. An antenna according to claim 8 wherein said non-reflective portion comprises a strip of electromagnetic wave energy absorbing material mounted on the surface of said paraboloidal reflector.

11. An antenna comprising a radiating means and a reflector, said reflector being shaped as a paraboloidal surface normally adapted to reflect radiant energy in a pencil type beam along a main path, a portion of said reflector being non-reflective, said non-reflective portion being generally quadrilateral in shape and extending substantially the full distance across said reflector, the long edges of said portion lying along lines of intersection with said reflecting surface of two parallel planes spaced equidistant on opposite sides of, and parallel to, a plane through the focal point of said reflector and disposed at an angle to the reflector axis, said portion being effective to modify the reflective characteristics of said reflector whereby a differently shaped energy distribution pattern is produced.

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