March 8, 1955 W. D. LEWIS 2,703,842

RADAR REFLECTOR

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FIG. 1.

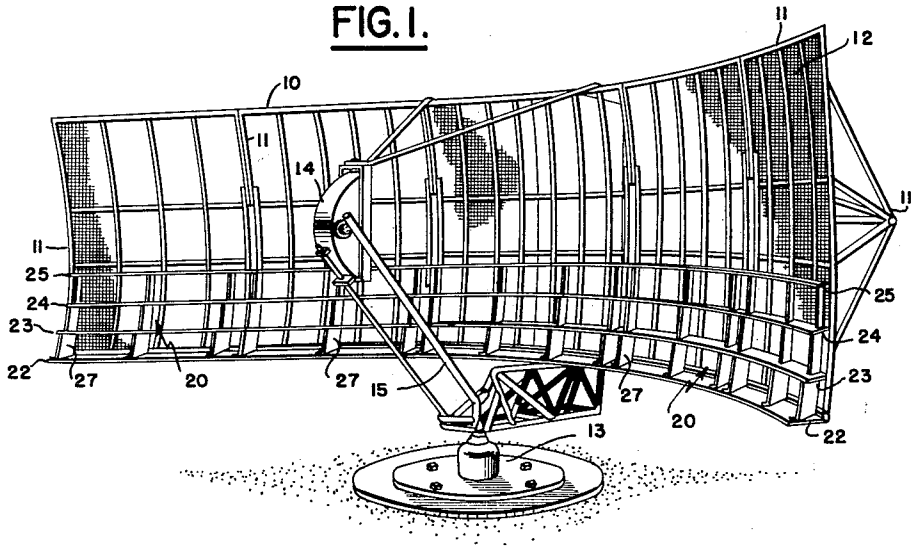


FIG. 2.

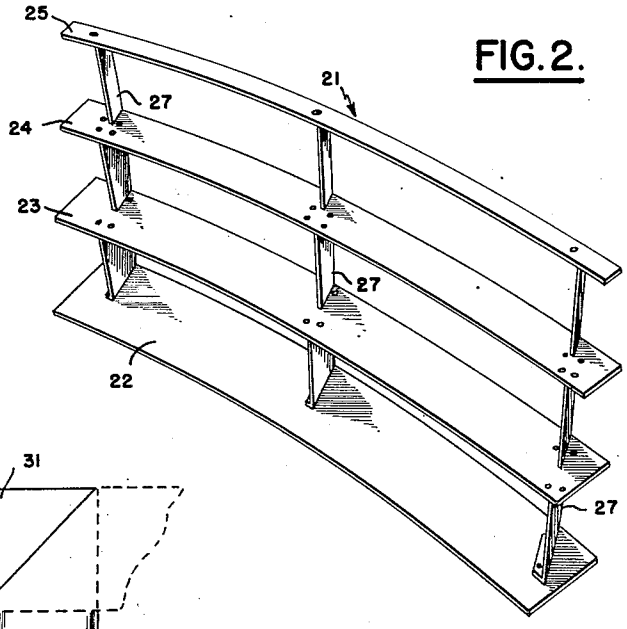
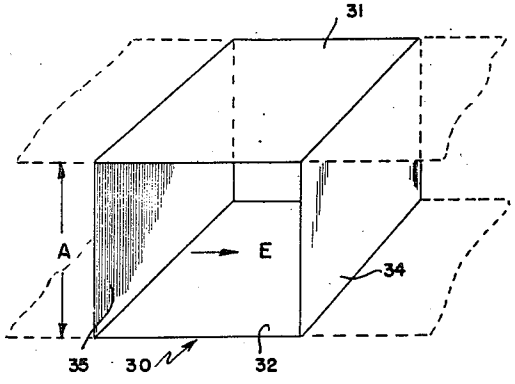


FIG. 3.



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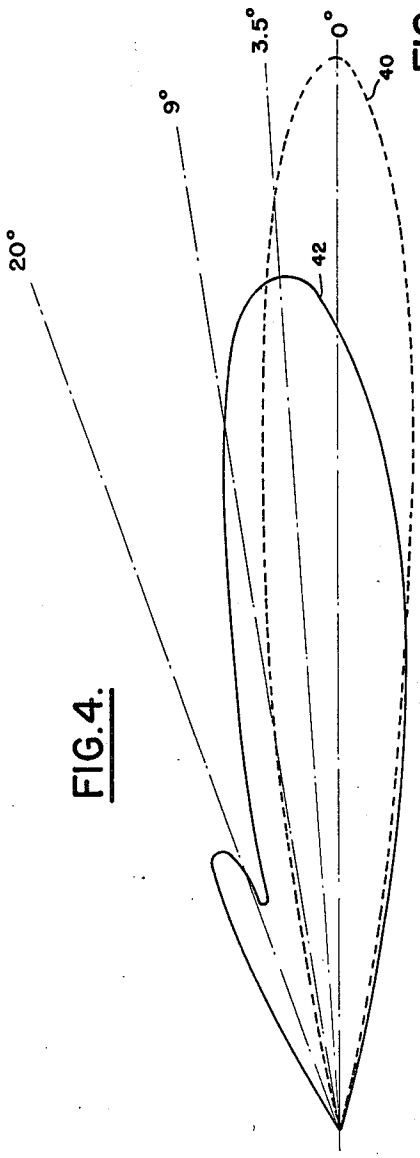


FIG. 4.

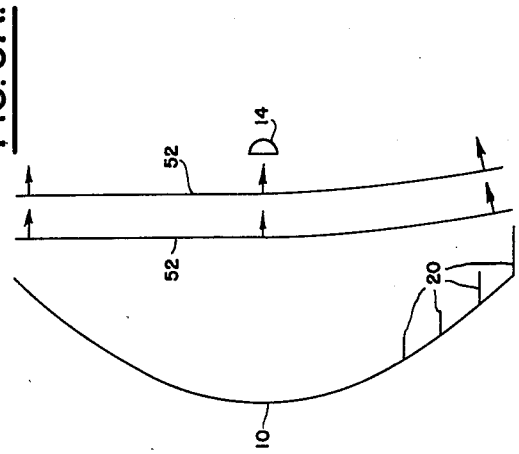


FIG. 5A.

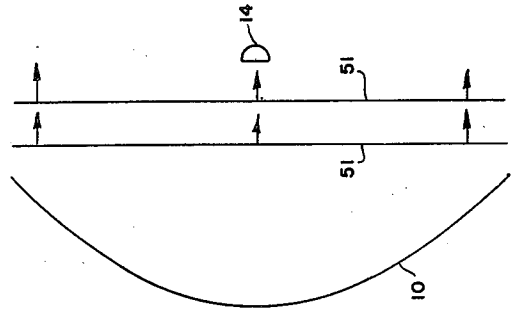


FIG. 5.

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RADAR REFLECTOR

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Application March 8, 1950, Serial No. 148,454

4 Claims. (Cl. 250—33.65)

The present invention relates to paraboloidal antenna reflectors and more particularly to a means for modifying paraboloidal reflectors to produce an unsymmetrical radiation pattern therefrom.

It is well known that the radiation pattern of a particular antenna reflector depends upon the method of supplying power to the antenna and upon the physical characteristics of the reflector itself. Since both the antenna feed arrangement and the reflector itself are fixed at the time of manufacture, it is difficult to change the construction of the installation, and changes made under field conditions are usually unreliable.

For many purposes, the radiation pattern of an antenna should be specially shaped to cover a desired area and the ordinary sharp lobe pattern of a conventional antenna system is not suitable. In order to provide a broad pattern in a vertical plane while retaining a sharp pattern in a horizontal plane as is required in an anti-aircraft search installation, it has been possible to use a plurality of feed points, all or some of which are displaced from the focal point of the reflector in the plane which is to be broadened from the normal pattern. Somewhat similar results can be obtained by employing a specially shaped antenna reflector. The desired beam pattern may be symmetrical about the axis of the reflector as is the case with a height-finding radar installation, or it may be unsymmetrical; i. e., it may radiate more power above the axis than below it in the case of an anti-aircraft search radar. However, such installations are also fixed in the manufacture, and the equipment is not flexible in application.

The present invention overcomes these objections in presently available apparatus by providing a simple inexpensive means for changing the effective radius of predetermined portions of a parabolic reflector by attaching a phase advancing means over the reflector.

The phase advancing means consists of a series of parallel conducting plates spaced from each other by a distance between a half and a full wavelength at the operating frequency and parallel to the polarization axis of the electromagnetic wave to be reflected. The portion of the reflector not covered by the phase advancing means remains unaffected while the effective radius of the covered portion is reduced, so that the reflector now behaves as though it were fed from a plurality of points or as though its physical shape had been changed. Since the phase advancing means is easily removable, the installation may be changed by only changing or removing the phase advancing means.

An object of the present invention is to provide a reliable method of modifying the radiation pattern from an existing reflector system.

Another object of the present invention is to provide a method of modifying the radiation pattern from an existing reflector which does not otherwise affect the operation of radar equipment.

A further object of the present invention is to provide an inexpensive and rugged method of modifying the radiation pattern of an existing antenna reflector system.

A still further object is to provide a means for shaping the radiation pattern of a conventional radar antenna reflector to provide a broad beam in a desired plane.

An additional object of the present invention is to provide an easily changed means for producing a preselected antenna radiation pattern from a parbolic reflector.

Other objects and advantages of the present invention will be made more apparent by reference to the following specification and by reference to the appended drawings in which:

Fig. 1 is a perspective view of the phase advancing unit of the present invention applied to the reflector of a search radar installation;

Fig. 2 is a view showing the construction of a section of the phase advancing unit shown in Fig. 1;

Fig. 3 is a diagram illustrating the effect of conducting plates on an electromagnetic wave;

Fig. 4 is a diagram showing the vertical pattern of the reflector shown in Fig. 1 before and after modification; and

Figs. 5 and 5A are a diagrammatical showing of the operation of the phase advancing means.

Referring now to Fig. 1, the symmetrically cut paraboloidal reflector **10** is composed of a frame **11** and a reflecting covering **12** which forms a section of a paraboloid. The frame **11** may be composed of any material which is strong and light, such as steel or aluminum tubing, and the reflecting covering **12** may be of conducting material such as metallic mesh or sheet metal, as is well known. It will be appreciated that the type of reflector may vary widely, and that the type shown is only for purposes of illustration. The reflector is mounted on a pintle **13** and is revolved at a suitable rate of speed by any convenient source of power, the exact arrangement used being a matter of design, and since it forms no part of the present invention it will not be further explained.

The reflector **10** is fed by a horizontally polarized electromagnetic wave through a wave guide **15** from the transmitter, the wave guide being equipped with directing means **14** to distribute the radiated energy over the reflector. The energy is reflected in a predetermined pattern which is controlled by the shape and size of the reflector, which are fixed characteristics of the particular reflector. The pattern is therefore fixed for a particular installation, and a typical example is shown by the wave **40** in Fig. 4.

The phase advancing unit **20** is added to the bottom portion of the reflector **10** to redirect the energy striking the bottom portion of the reflector by progressively altering the effective radius of the bottom portion of the reflector **10**. The phase advancing unit **20** consists of a plurality of parallel plates **22**, **23**, **24** and **25** spaced from each other by a distance of slightly more than a half-wavelength, the width of the plates increasing progressively as the distance of the plate from the center of the reflector increases. The plates are assembled on a plurality of vertical spreaders **27** which support the plates at the desired intervals and also aid in holding the phase advancing means **20** to the reflector **10**. Any type of fastening means may be employed to attach the plates to the reflector covering **12** or the reflector frame **11** as desired, such as a plurality of U-bolts equipped with plates and wing nuts. Electrical connection with the reflecting surface is unimportant, but the attachment should be secure so as to prevent shifting of the plates relative to the reflector.

For convenience in mounting and storing the phase advancing unit **20** when not in use, the unit is composed of a plurality of sections **21**, which sections may correspond to the sections of the reflector **10**. The phase advancing sections **21** need not be removed from the reflector **10** when it is disassembled for movement, if the unit is properly sectionalized. A phase advancing section **21** is shown in Fig. 2.

It is well known that the phase velocity of a wave in a wave guide is higher than the speed of the wave in air. Referring now to Fig. 3, the rectangular tube **30** represents a wave guide for a horizontally polarized radio frequency system, the electrical vector being represented by E. The separation A of the horizontal surfaces **31** and **32** determines the mode of operation of the wave guide at a particular frequency and also establishes the minimum frequency at which it may be operated. The vertical surfaces **34** and **35** serve only to bound the region where power is transmitted and do not otherwise affect the transmission. In the present case, the width of the horizontal

sides **31** and **32** in the direction of the vector E is increased to the length of the reflector. In Fig. 1 the only elements corresponding to the vertical sides **34** and **35** are the spreaders **27**. The phase velocity is determined by the separation of the plates and the phase advance produced by the plates is proportional to the width of the parallel plates.

The ratio N of the velocity of a wave in air to the phase velocity in the wave guide is given by the equation:

$$N=\sqrt{1-\left(\frac{\lambda}{2A}\right)^2}$$

where
A=the spacing between the plate, and
λ=the operating wavelength.

An inspection of the above equation will show that N will be finite for values of A larger than $\lambda/2$, and will be less than unity. Thus the velocity of a wave passing between the plates will be higher than in open air, so that the insertion of a series of parallel plates between a power source and a reflector has the effect of moving the reflector toward the power source by an amount proportional to the width of the plates, thus changing the effective radius of the reflector.

The addition of the phase advancing unit **20** to the reflector **10** produces the effect of two reflectors radiating energy from a single source, since the portion of the reflector not covered by the unit **10** is not changed in any way and produces the same wave front as before the unit was added. However, the portion of the reflector **10** covered by the phase advancing unit **20** now has a different radius and focal point so that it reflects power in a lobe which is angularly displaced from the original pattern, so that the combined radiation pattern is considerably widened although its length is somewhat shortened.

The width of the plates **22**, **23**, **24** and **25** in the phase advancing unit **20** are proportioned so as to produce a smooth wave front from the portion of the reflector covered thereby. In the present example, the plates increase progressively in width from the plate **25** nearest to the center of the reflector **10** to the plate **22** farthest therefrom. As a result, the wave front is bent so that the lower portion leads the remainder, as shown in Fig. 5A. However, it will be clear to those skilled in the art that other shapes of wave front can also be readily produced by properly selecting the widths of the plates.

The relative power in the lobes from the covered and the uncovered portions of the reflector may be proportioned by changing the relative areas thereof, since the radiant energy to be reflected is distributed over the area of the reflector in a substantially uniform manner. Since the angular displacement of the lobes from the covered and uncovered portions of the reflector is determined by the width of the several plates, and the power of the respective lobes may also be controlled, it is apparent that a wide variety of radiation patterns may be produced by the proper design of the phase advancing unit.

Figs. 5 and 5A show the effect of the phase advancing unit applied to a reflector. In Fig. 5, the electromagnetic wave energy from the feed reflector **14** is reflected by the reflector **10** to form substantially straight wave fronts as indicated by **51**, and since the direction of radiation is perpendicular to the wave front, the pattern produced will be a sharp beam. In Fig. 5A, a phase advancing unit **20** is added to the lower half of the reflector **10**, and the wave fronts **52** which are now radiated are deviated with the lower edge leading the remainder of the wave front. It will be observed that a portion of the radiated energy has been deflected upwardly to produce an unsymmetrical radiation pattern with respect to the axis of the reflector in which the upper portion of the lobe produced contains considerably more power than the lower portion, and that the radiation pattern has been "fanned out" in a vertical direction.

In the present illustration, a large portion of the power in the lower half of the normal radiation pattern is shifted to the upper half, thus producing a substantial increase in the vertical angular coverage above the axis of the reflector without a substantial reduction in the angular coverage below the axis. The power distribution and hence the range of the radar installation in a given direction is, of course, altered and at some elevations it is reduced while at others it is increased. However the tactical value of the unit in covering a substantial area is greatly increased by "spreading" or shaping the beam in the vertical plane to produce a more desirable radiation pattern for radar search purposes.

The effect of the phase advancing unit **20** on the radiation pattern in a vertical plane through the center of the reflector **10** may be readily seen by reference to Fig. 4. The radar antenna without the phase advancing unit radiates a pattern similar to that illustrated by the curve **40**, which pattern is relatively sharp and symmetrical about the axis **41** of the reflector **10**. It will be noted that the beam thus produced covers a chord of a circle of about $\pm 9°$. When the phase advancing unit **20** is added to the reflector **10**, the pattern is illustrated by the curve **42**, which covers a sector which extends from about 10° below the axis **41** to more than 20° above the axis. The power produced by the radar transmitter is now distributed in a pattern which more closely approaches the optimum pattern for an anti-aircraft search radar.

It will be readily seen that a wide variety of patterns may be produced from a particular type of high frequency equipment by a proper selection of phase advancing units, and since the units are quickly changeable, a selection of the desired radiation pattern may be made for each operating station if it should be so desired. The particular installation shown and described is intended to be only an illustration of the present invention.

Having described the present invention, what is claimed is:

1. In a high frequency radio antenna system, a paraboloidal reflector having a horizontal plane of symmetry, a feeding device for supplying thereto electromagnetic wave energy having a polarization axis parallel both to said reflector and to said plane, and a plurality of metallic plates projecting from a section of the reflecting surface of said reflector parallel with said plane, adjacent plates being separated by a distance in excess of one-half of the wavelength of said electromagnetic wave energy and the width of said plates being proportioned to advance the wave front radiated by said section of said reflector increasingly as the distance from said plane increases.

2. In combination, a paraboloidal reflector having a horizontal plane of symmetry which substantially includes the axis of the radiation pattern therefrom, a feeding device for supplying horizontally polarized electromagnetic wave energy to said reflector, and a plurality of parallel metallic plates having their major axis parallel to the polarization of said polarized wave energy and parallel to the axis of the radiation pattern of said reflector, said plates being attached to the section of said reflector adjacent a vertical extremity thereof, adjacent plates being separated by a distance in excess of one-half the wavelength of said wave energy, and the width of said plates increasing progressively as the vertical distance of the plate from said plane increases, whereby the radiation pattern from said reflector is substantially broadened in a vertical plane.

3. In combination, a symmetrically cut paraboloidal reflector having a horizontal major axis and a horizontal plane of symmetry which substantially includes the axis of the radiation pattern therefrom, a feeding device for radiantly distributing horizontally polarized electromagnetic wave energy over the reflecting surface of said reflector, and a plurality of metallic plates removably attached to the reflecting surface substantially parallel to the direction of radiation from said reflector, said plates being coextensive with the horizontal length of said reflector and parallel with said plane, adjacent plates being separated by a distance in excess of one-half the wavelength of said wave energy, the width of each of said plates being in accordance with a function of its vertical displacement from said plane, and the widest of said plates being attached to the reflector adjacent the lower extremity thereof, whereby energy is deflected from the lower to the upper portion of the normal radiation pattern of said reflector when said plurality of plates is attached thereto.

4. In an ultra-high frequency antenna system, a paraboloidal reflector having a plane of symmetry which substantially includes the axis of the radiation pattern therefrom, a feeding means for supplying thereto electromagnetic wave energy having a polarization axis parallel both to said reflector and to said plane, and a plurality of parallel plates parallel to the axis of the radiation from

said reflector separated from each other by a distance in excess of one-half the wavelength of the wave energy, said plates being adapted to be removably attached to the reflecting surface of said reflector adjacent an extremity thereof and parallel with said plane, and the width of each of said plates being selected in accordance with a function of the displacement of the plate from said plane, whereby the radiation pattern of said reflector is broadened from the normal radiation pattern when said plates are attached to said reflector.

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