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2,930,039

ANTENNA SYSTEM FOR VARIABLE POLARIZATION

Filed Oct. 18, 1954

3 Sheets-Sheet 1

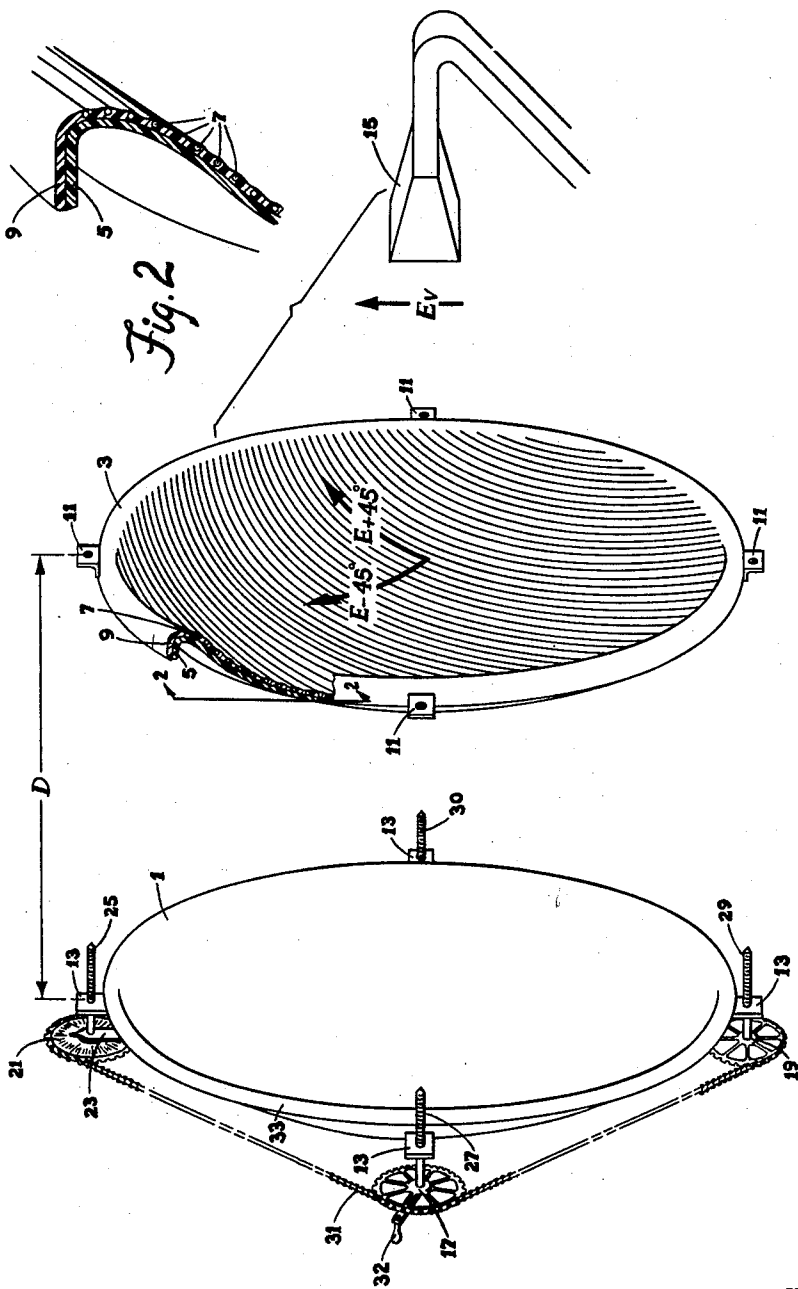


Fig. 1

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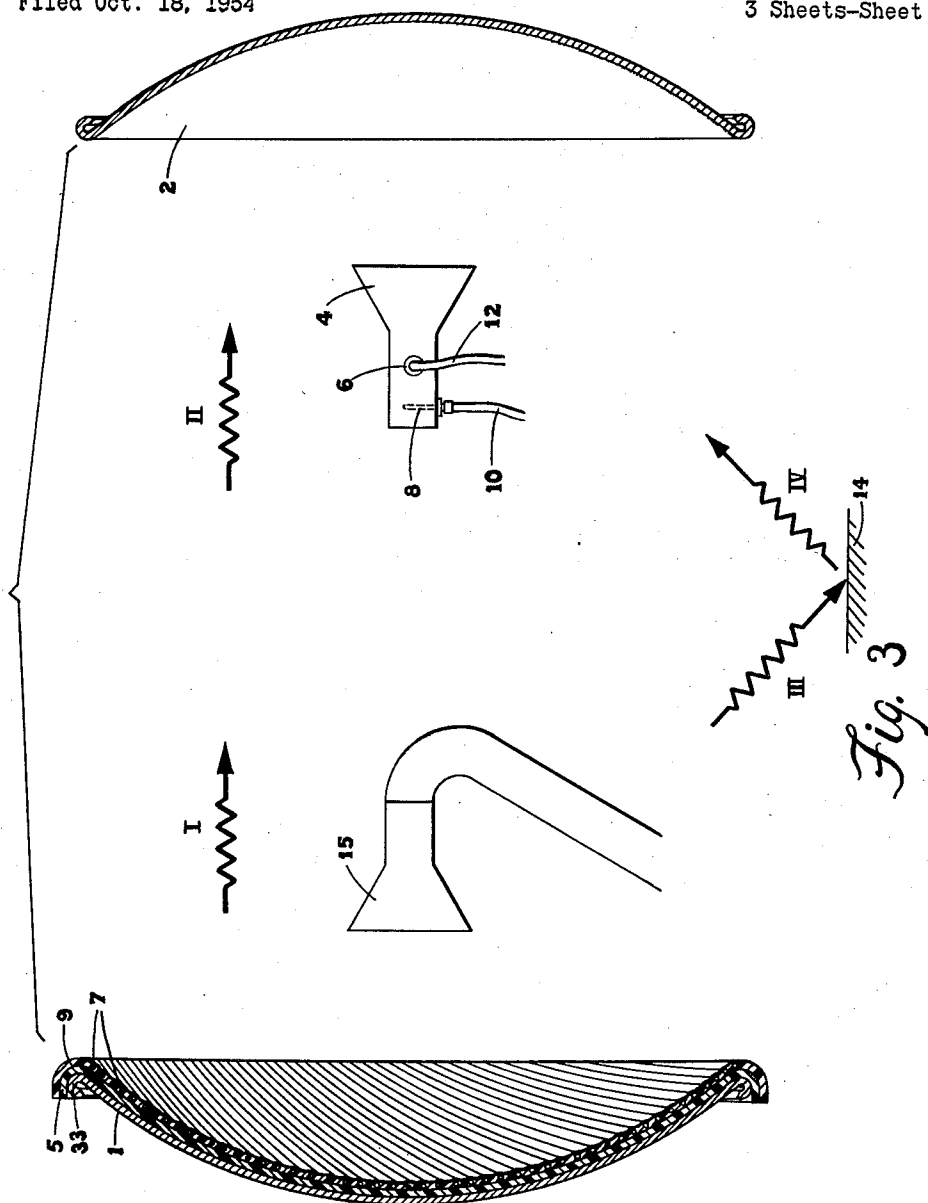
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3 Sheets-Sheet 2



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3 Sheets-Sheet 3

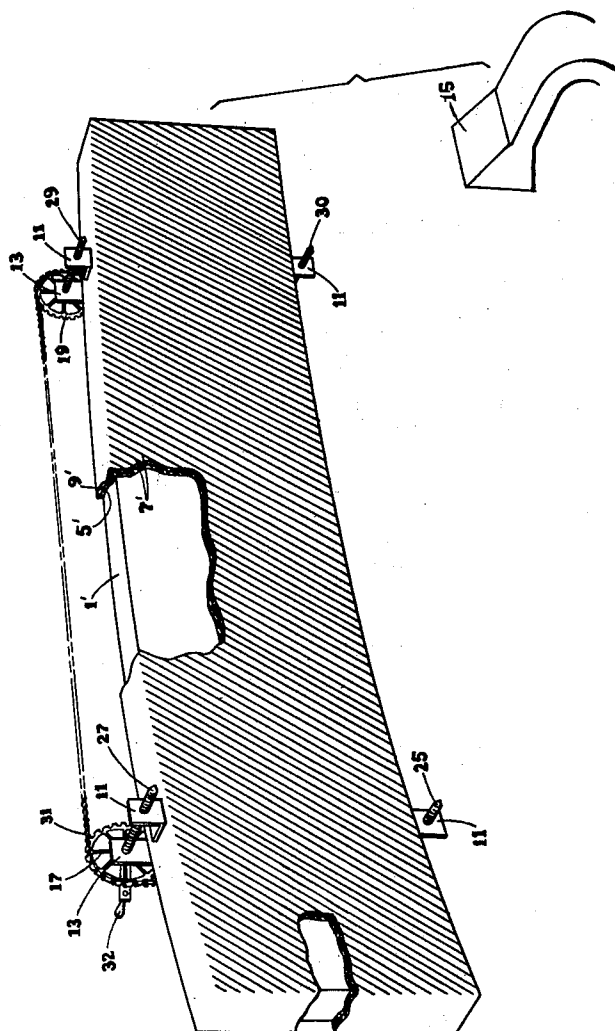


Fig. 4

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ANTENNA SYSTEM FOR VARIABLE
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5 Claims. (Cl. 343—756)

The present invention relates to radio-wave antenna systems and more particularly to such systems in which it is desirable to alter at will the polarization of the radio waves transmitted or received by the antenna systems.

Various techniques have heretofore been proposed for changing the polarization of radio waves transmitted by an antenna. The antenna may be oriented along successively different directions to alter the direction of polarization of the electric vector associated with the radio waves, or a plurality of differently oriented antennas may be selectively phased or otherwise switched to produce a desired polarization angle. Dielectric media such as gas-filled chambers and the like have been proposed for placement in the path of the waves transmitted by the antenna to modify the polarization in accordance with the refractive-index properties of the media. Various arrangements of parallel-wire grid combinations have also been utilized to attain a shift in the polarization of the waves. These prior-art techniques, however, are not wholly practical for many types of antenna systems. It is difficult, for example, to attempt to change the orientation of the feed at the focus of many types of parabolic reflector systems, such as unsymmetrical reflector systems and systems provided with complex feed structures as employed in scanning and monopulse radar apparatus, in order to effect a polarization change. As another illustration, it is difficult with present-day techniques to obtain wide-frequency-band circular polarization operation. It is equally complex to attempt to use a plurality of differently oriented and phased antennas in the feed system. Additional physical limitations in polarization-changing apparatus are imposed in the case of radar antennas and the like that must rotate freely and often at very high speeds.

An object of the present invention is to provide a polarization-changing antenna apparatus that shall not be subject to any of the above-mentioned disadvantages and that, to the contrary, is particularly adapted for use with reflector focusing or collimating systems such as those used in radar apparatus and radio communication systems.

A further object is to provide a new and improved antenna.

An additional object is to provide a safeguard in a radio or radar system and the like against jamming through the facility of polarization-changing by the operator, which enables discrimination against jamming signals.

Still another object is to provide such an antenna in which, at the will of the operator, the polarization can easily be changed from linear polarization along one angle, to complementarily oriented linear polarization, or to circular polarization. This end is achieved, in accordance with the invention, through the use of an appropriately shaped and oriented grid of closely spaced parallel conductors mounted adjacent the reflecting sur-

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face between the same and the focal region thereof and movable toward and away from the reflecting surface within predetermined limits.

An important application of the invention, as before stated, is in radar antennas where discrimination between targets of different reflecting properties can be attained by changing the polarization until the desired signal contrast is achieved. Many radio-echoing targets, such as telephone lines, railroad tracks, vessel structures and the like have definite polarization characteristics and can therefore be rendered more clearly discernable on radar displays by the proper choice by the operator of the polarization of the incident radio waves from the radar. Discrimination between desired targets and rainfall, for example, is known to be improved with circularly polarized waves. In accordance with the present invention, the operator may easily vary the type of polarization to obtain the optimum condition that he seeks, changing from linear to circular polarization at will, or changing the type of linear polarization. The invention is also useful in relay communication systems to obviate fading effects as later explained. In all cases, however, the invention provides a highly practical and commercial technique for changing polarization that is equally adaptable for stationary and rotating or rocking antenna systems.

Other and further objects will be explained hereinafter and will be more particularly pointed out in the appended claims.

The invention will now be explained in connection with the accompanying drawings,

Fig. 1 of which is a perspective view of the invention with the parts shown exploded to illustrate details of construction and assembly;

Fig. 2 is a fragmentary section taken along the line 2—2 of Fig. 1, upon an enlarged scale;

Fig. 3 is a longitudinal section of the assembled apparatus of Fig. 1, as employed in a circular-polarization transmitting-and-receiving system; and

Fig. 4 is a perspective view of a preferred form of the invention.

A paraboloidal reflector that may, for example, be incorporated in a radar antenna or an ultra-high-frequency or microwave communication antenna, is shown at 1. While the invention is applicable to any type of reflecting surface, including those shaped to yield a co-secant-squared radiation pattern, as will later be evident from the description of the operation of the invention, it is particularly adapted for use with beam-producing reflectors 1 having a focal region at which a transmitting or receiving antenna, such as, for example, a wave-guide horn 15 or any other desired type of antenna, may be disposed, as is well known. Considering, for example, the horn 15 as a transmitting device, though the same but reverse considerations apply in connection with its use as a receiver, it will impinge radio waves upon the reflecting surface 1 whence the waves will be directed as a parallel-ray beam into space for such purposes as radar location or point-to-point radio communication. Interposed between the focal region of the reflector 1 at which the horn or other antenna 15 is disposed and the reflector 1 is a grid of substantially parallel spaced conductors 7. These conductors 7 are preferably of wire or rod form embedded within a dielectric layer 9, such as Fiberglas. The Fiberglas layer 9 may, in turn, be supported by one or more further dielectric layers 5, as of Fiberglas, the whole assembly 5, 7, 9 being shaped into a paraboloidal surface of substantially the same contour and dimensions as the reflecting surface 1. The assembly 5, 7, 9 may be fabricated by assembling the Fiberglas layers with the grid conductors 7, covering the same with a plastic resin,

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and subjecting the assembly to pressure upon a mold of the desired paraboloidal or other shape until hardened. A convenient apparatus and technique for achieving this result, for example, is described in copending application, Serial No. 308,363, filed September 8, 1952, by Frederick R. Hart, Jr. Alternatively, the Fiberglas layer or layers may be placed upon a cast or otherwise preformed reflector. The wires 7 may be stretched about a male plaster mold of the same shape which is then pressed with resin against the Fiberglas-covered reflector. After heat-curing, the ends of the wires may be cut and the assembly 5, 7, 9 is then ready for mounting.

If it be assumed that the electric-vector polarization of the waves transmitted or received by the antenna 15 is, for example, substantially vertical, as indicated by the vector E_v , the grid conductors 7 should be oriented at substantially forty-five degrees with respect to the vertical. While the orientation is shown as forty-five degrees clockwise or $+45^\circ$ in Fig. 1, it could equally well be forty-five degrees counterclockwise or -45° . The waves of vertical electric vector E_v can be considered as having two complementary components shown by the vectors E_{-45° and E_{+45° . The E_{+45° component will be reflected back by the wire grid 7 if the cross-dimension of the conductors 7 and the spacing between the conductors 7 are small compared with the wavelength of the impinging waves from the horn 15. The waves of component E_{-45° , on the other hand, will pass right through the grid 7 and the dielectric layers 5, 9 to impinge upon and be reflected back from the reflector 1 itself. Depending upon the separation D between the reflector 1 and the grid 7, the waves reflected from the reflector 1 will be delayed in phase compared with the waves reflected from the grid 7, producing resultant beams of reflected energy of different polarizations.

If the separation D and the dielectric properties of the layers 5, 9 are such that the waves E_{-45° reflected from the reflector 1 return to the grid 7 in the same phase that they originally had when passing through the grid 7 on the way to the reflector 1, then the resultant beam transmitted into space will have the vertical polarization E_v . If, on the other hand, the phase of the reflected waves E_{-45° is ninety degrees, or an odd multiple thereof, different from the original waves E_{+45° at the grid 7, then these ninety-degree phase-shifted waves E_{-45° will combine with the waves E_{+45° to form a circularly polarized beam the electric vector of which may rotate either clockwise or counterclockwise. As still another illustration, if the phase shift of the E_{-45° reflected waves is one-hundred eighty degrees, or an odd multiple thereof, the E_{-45° component will be out-of-phase with that shown in Fig. 1 and will combine with the E_{+45° waves reflected from the grid 7 to form horizontally polarized waves of electric vector perpendicular to E_v . Should, moreover, the amplitude of the reflected components E_{-45° and E_{+45° be unequal, elliptically polarized waves may be produced.

In accordance with the present invention, variation at will between these various polarized states can be accomplished merely by varying the distance D between the grid 7 and the reflector 1, thereby to vary the phase shift of the E_{-45° wave-component reflected from the reflector 1. This variation of the distance D must be accomplished, however, with the grid 7 everywhere spaced substantially equidistant from the reflector 1 in order to produce the same phase shift at all parts of the reflector 1. Particularly in the case of unsymmetrical reflector systems, the grid 7 may be spaced somewhat closer to the reflector at the edges than intermediate the same, but the grid-to-reflector spacing will, however, be substantially constant. A convenient apparatus for effecting this result embodies four threaded screws 25, 27, 29, 30 passed through mounting plates 13 preferably equally spaced along the periphery of the reflector 1. The mounting

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plates 13 are shown provided to the rear of the reverse bead 33 along the periphery of the reflector 1, extending radially outward beyond the periphery. The right-hand ends of the screws 25, 27, 29, 30 will receive similar mounting plates 11 provided at points along the top of the reversely curving bead 3 of the grid 7. Through simultaneous rotation of the screws 25, 27, 29 and 30 by corresponding synchronously operated gears 21, 17, 19, etc., the distance D can thus easily be varied at the will of the operator. Turning of the handwheel 32 will drive the gear 17, and through the chain 31, the gears 21, 19, etc. The value of D and hence the state of the resultant polarization may be conveniently indicated to the operator by a pointer 23 cooperating with a calibrated scale shown carried by the gear 21. These operations may, of course, be performed remotely by electric or hydraulic driving means, not shown, well-known in the art.

As an illustration, if it is desired to enable the operator to shift the polarization from vertical to circular to horizontal polarization, which is extremely useful in radar operations in order to obtain different selective echoing effects from various objects or better to detect objects under different atmospheric conditions, the limits of variation of the separation D should be adjusted so that the electrical one-way path between the grid 7 and the reflector 1 varies from about zero to about one-half the wavelength of the radio waves with which the antenna is utilized. With zero spacing the grid 7 is adjacent to the reflector 1 and the E_{-45° waves will not be phase-shifted in traveling from the grid 7 to the reflector 1 and then back to the grid 7. This will produce a resultant beam of vertically polarized waves. For a one-eighth wavelength spacing, circularly polarized waves will be produced. With the one-way electrical path between the grid 7 and the reflector 1 corresponding to one-quarter the wavelength, the total phase shift of the waves returning from the reflector 1 to the grid 7 will be one hundred eighty degrees, producing a resultant horizontal polarization. A one-way electrical path of one-half the wavelength will produce a total phase shift of three hundred sixty or zero degrees, giving rise to a resultant vertical polarization E_v in the radiated beam.

As an illustration, a suitable apparatus of the character described for use with microwaves of three centimeters wavelength may employ wire conductors 7 of about twenty thousandths of an inch diameter spaced about one-eighth of an inch apart and imbedded in a Fiberglas layer or layers of dielectric constant equal to about 4 and of about one-sixteenth of an inch thickness. With the grid 7 displaced from the reflector 1 about one-sixteenth of an inch, one-eighth of an inch and three-eighths of an inch, circular, vertical and horizontal polarization may respectively be obtained.

Instead of the manual control 32, of course, a motor-driven control, not shown, could be employed, as before indicated, periodically to vary the polarization of the beam or to move the grid 7 to the desired location D where the desired polarization is obtained. If a fixed polarization, such as circular polarization, is desired, of course, the assembly 5, 7, 9 may be cemented or otherwise secured to the reflector 1, as shown in Fig. 3. For such circular polarization, the separation between the reflector 1 and the grid 7 will be sufficient to produce the before-described one-eighth wavelength one-way electrical path, with a two-way phase shift from the grid 7 to the reflector 1 and then back to the grid 7 of ninety degrees. This particular system is extremely useful for ultra-high-frequency or microwave point-to-point communication where the transmitted energy is received at a receiving antenna, shown in Fig. 3 as a paraboloidal reflector 2 having a receiving horn 4 at its focus. In actual practice, the reflector 1 and the reflector 2 will, of course, be separated by many miles. The radio waves transmitted from the reflector

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1 will reach the reflector 2 along two paths. The first path is the direct or line-of-sight path represented by the arrows I, II. The other path is the reflected path illustrated by the arrow III shown hitting the ground 14 and reflecting therefrom along the direction of the arrow IV toward the reflector 2. Heat striations from buildings or other phenomena at the ground 14 cause variations in the phase and amplitude of the reflected waves along the path IV so that such waves arrive at the reflector 2 in different states at different times to produce different interference cancellation or re-enforcement effects with the direct waves reaching the reflector 2 along the path I, II. This gives rise to fading of the received signal. With the circular-polarizing apparatus 1, 5, 7, 9, however, the reflected wave along the path III, IV can be effectively discriminated against at the receiver. The receiving horn 4 is shown provided with a vertical probe antenna 8 and a horizontal probe antenna 6 connected by appropriate lengths of the respective transmission lines 10 and 12 to a receiving apparatus, not shown. The probes 6 and 8 will pick up the horizontal and vertical polarization components of the circularly polarized wave transmitted from the antenna 1, 5, 7, 9. The radial electric vector of this circularly polarized wave may rotate, for example, clockwise. The transmission lines 12 and 10 will then be adjusted to produce an appropriate ninety-degree phase shift in the received horizontal and vertical polarization components of the clockwise rotating circular polarized beam picked up by the probes 6 and 8. Such clockwise-circular-polarized received waves will thus be detected in the receiver. Any reflected wave traveling along the path III, IV, however, suffers substantially a one-hundred eighty degree phase shift in the reflection process at the ground 14, or variations therefrom due to the phenomena before described, so that the waves received at 2 along the path IV will be counter-clockwise-rotating circularly polarized waves or waves of some other polarization state than the clockwise-circular-polarization state of the direct waves along the path I, II. The receiving system 4, 6, 8, 10, 12, however, is adapted only to receive the clockwise circular polarized waves, as above explained, so that the reflected waves received along the path IV are always discriminated against. The use of the present invention in such a microwave communication link can therefore minimize fading effects. It is also to be observed that the system of Fig. 3 can also discriminate against other types of interfering signals.

The invention is not, of course, limited to reflectors of the particular paraboloidal shape heretofore described or, for that matter, to paraboloid configurations. Another convenient shape for radar applications, for example, involves substantially a cylindrical section of a paraboloid as shown at 1' in Fig. 4. The assembly 5', 7', 9' will correspond to the assembly 5, 7, 9 of Fig. 1 except that it will assume the cylindrical paraboloidal form shown in Fig. 4 with the edges overlapping the edges of the reflector 1' on the top, bottom and sides thereof. It is also to be understood that the grid-reflector antenna of the present invention is useful for both transmission and reception purposes.

Further modifications will occur to those skilled in the art and all such are considered to fall within the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. A radio-wave antenna for operation with radio waves of a predetermined wavelength comprising a curved reflecting surface having a focus, a grid of substantially parallel conductors disposed along a surface of substantially the same curvature and dimensions as the reflecting surface and having substantially the same focal length, means for supporting the grid directly from the periphery of the reflecting surface between the re-

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fecting surface and the focal region and everywhere substantially equidistant from the reflecting surface, and means cooperative with the supporting means for varying the separation between the grid and the reflecting surface up to about one-half the said predetermined wavelength while maintaining the said substantially equidistant relationship throughout the variation of separation.

2. A radio-wave antenna for operation with radio waves of a predetermined wavelength comprising a curved reflecting surface having a focus, a grid of substantially parallel conductors spaced from one another a distance much less than the said predetermined wavelength and disposed along a surface of substantially the same curvature and dimensions as the reflecting surface and having substantially the same focal length, means for supporting the grid directly from the periphery of the reflecting surface everywhere substantially equidistant from the reflecting surface, and means cooperative with the supporting means for varying the electrical path between each conductor of the grid and the corresponding part of the reflecting surface up to about one-half of the said predetermined wavelength while maintaining the said substantially equidistant relationship throughout the variation of path.

3. A radio-wave antenna comprising a curved reflecting surface having a focus, means for transmitting to or receiving from the reflecting surface radio waves of a predetermined wavelength and angle of polarization, a grid of substantially parallel conductors of negligible cross dimension compared to the said wavelength oriented at an angle substantially forty-five degrees displaced from the said angle of polarization and spaced from one another a distance much less than the said predetermined wavelength, the conductors of the grid being disposed along a surface of substantially the same curvature and dimensions as the reflecting surface and having substantially the same focal length, means for supporting the grid directly from the periphery of the reflecting surface everywhere substantially equidistant from the reflecting surface, and means cooperative with the supporting means for varying the electrical path between each conductor of the grid and the corresponding part of the reflecting surface up to about one-half of the said predetermined wavelength while maintaining the said substantially equidistant relationship throughout the variation of path.

4. A radio-wave antenna comprising a reflecting surface having a contour that follows a paraboloid or a section thereof, means disposed substantially at the focus of the reflecting surface for transmitting to or receiving from the reflecting surface radio waves of a predetermined wavelength and angle of polarization, a grid of substantially parallel conductors of negligible cross dimension compared to the said wavelength supported by a dielectric layer at an angle of substantially forty-five degrees with respect to the said angle of polarization and spaced from one another a distance much less than the said wavelength, the grid and the dielectric layer being shaped along a surface of substantially the same curvature and dimensions as the reflecting surface and having substantially the same focal length, means comprising cooperative mounting plates connected with the reflecting surface and the grid and dielectric layer for supporting the grid and dielectric layer directly from the periphery of the reflecting surface everywhere substantially equidistant from the reflecting surface, and means for varying the spacing between the cooperative mounting plates up to about one-half said predetermined wavelength to vary the separation between the grid and dielectric layer and the reflecting surface while maintaining the said substantially equidistant relationship throughout the variation of separation.

5. A radio-wave antenna comprising a reflecting surface having a contour that follows a paraboloid or a

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section thereof, means disposed substantially at the focus of the reflecting surface for transmitting to or receiving from the reflecting surface radio waves of a predetermined wavelength and angle of polarization, a grid of substantially parallel conductors of negligible cross dimension compared to the said wavelength supported by a dielectric layer at an angle of substantially forty-five degrees with respect to the said angle of polarization and spaced from one another a distance much less than the said wavelength, the grid and the dielectric layer being shaped along a surface of substantially the same curvature and dimensions as the reflecting surface and having substantially the same focal length, means comprising cooperative mounting plates connected with the reflecting surface and the grid and dielectric layer for supporting the grid and dielectric layer directly from the periphery of the reflecting surface everywhere substan-

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tially equidistant from the reflecting surface, and means for varying the spacing between the cooperative mounting plates to vary the electrical path between the grid and the reflecting surface up to about one-half of the said wavelength while maintaining the said substantially equidistant relationship throughout the variation of separation.

References Cited in the file of this patent

UNITED STATES PATENTS

2,492,989	Halstead	Jan. 3, 1950
2,607,009	Affel	Aug. 12, 1952
2,680,810	Korman	June 8, 1954
2,736,895	Cochrane	Feb. 28, 1956

FOREIGN PATENTS

668,231	Germany	Nov. 28, 1938
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