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2,800,657

CIRCULARLY POLARIZING ANTENNA ASSEMBLY

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2 Sheets-Sheet 1

FIG. 1.

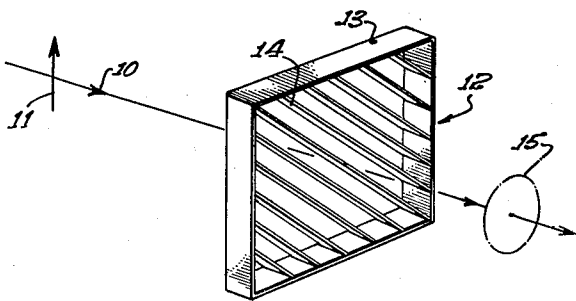


FIG. 2.

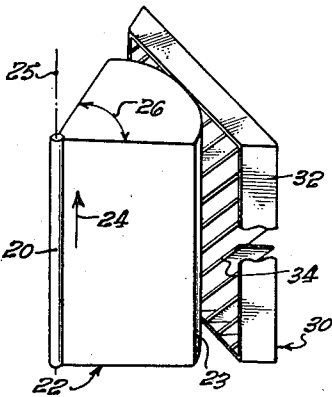


FIG. 4.

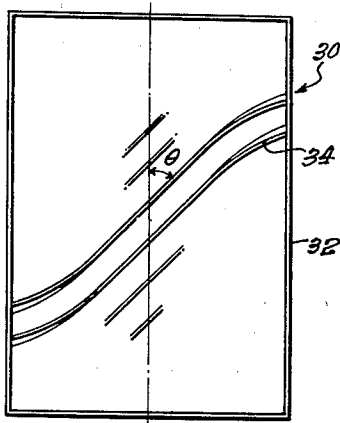


FIG. 3.

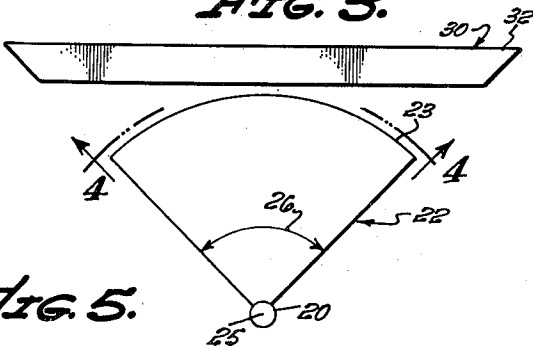
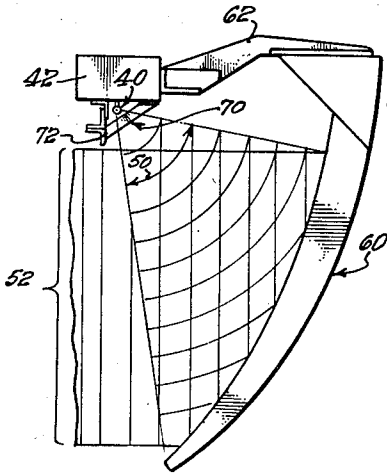


FIG. 5.



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CIRCULARLY POLARIZING ANTENNA
ASSEMBLY

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7 Claims. (Cl. 343—756)

This invention has to do with antenna means for producing and receiving circularly polarized electromagnetic radiation.

The invention is concerned more particularly with means for transforming an electromagnetic radiation field having substantially cylindrical wave fronts between linearly polarized and circularly polarized conditions.

It has previously been proposed to produce such modification of the state of polarization of a substantially cylindrical wave field by means of a polarization controlling grid of helical form, each vane of the grid forming a helical surface the axis of which substantially coincides with the cylindrical axis of the wave field. Such a polarization grid of helical form has been described, for example, in United States Patent 2,637,847. However, a polarized grid of that type is relatively expensive to manufacture, and the dimensional tolerances required for satisfactory operation have been found to be difficult to meet and to maintain. Those and other difficulties result primarily from the fact that the individual vanes are not flat, as in a plane grid intended for use in a radiation field having plane wave fronts. Instead, each vane must be twisted into helical form, and must be mounted in such a way as to maintain a degree of twist that is strictly uniform both throughout the length of each vane and among the several vanes of the entire grid. Any departure from such uniformity causes variation in the spacing of adjacent vanes, degrading the condition of polarization of the radiation field.

The present invention is particularly useful in connection with certain types of directional antenna means, such as are typically used for emitting sharply directional radar beams and for receiving reflected radar signals from a limited angle in space and with relatively high gain. Antenna systems for that purpose frequently utilize initial radiating means that produce a primary radiation field that is collimated in one coordinate and divergent in the other coordinate, such a radiation field typically having substantially cylindrical wave fronts. That primary radiation field is then subjected to collimating means that produce a secondary beam collimated in both coordinates. Such collimating means may typically comprise a cylindrical reflector having its axis parallel to the cylindrical axis of the primary radiation field. The initial radiating means of such an antenna system may, for example, comprise a linear antenna array of longitudinally aligned dipoles; means acting to supply the dipoles with electromagnetic energy of definite frequency either in phase or with progressive difference of phase that is suitably controlled to determine the direction of wave propagation in a plane through the axis of the array; and beam limiting means for controlling the angular divergence of the radiation in a plane transverse of the array axis. Such beam limiting means may typically comprise two plane reflectors arranged in planes parallel to the array axis and forming a dihedral angle that closely encloses that axis. The resulting primary radiation field that comprises wave

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fronts of generally cylindrical form but substantially limited to a definite dihedral angle about the axis of the source, that angle corresponding roughly to the dihedral angle formed by the planes of the reflectors. The dihedral angle of the wave field may, in practice, vary over a considerable range. The present invention, however, is concerned primarily with radiation fields of the type described having a dihedral angle of approximately a right angle. The cylindrical axis of such a wave field is typically at or close to the intersection of the planes of the reflectors, rather than at the axis of the antenna array. When the dihedral angle of such a cylindrical radiation field is of the order of 90° it is feasible to collimate the radiation beam by means of a cylindrical parabolic reflector that is used "off-axis." For initial beam angles much larger than 90° , an off-axis arrangement is usually not practicable, and the assembly of radiation source and limiting plane reflectors then tends to lie in the collimated secondary beam, interfering with a portion of the radiation. It will be understood, however, that such a system may be considered as two off-axis systems mounted back to back.

It has been discovered that the shifting of such cylindrical radiation fields between linear and circular conditions of polarization does not require a relatively complex grid of helical form, as would be expected, but can be accomplished satisfactorily by a simple plane grid, of the general type that has previously been supposed to be effective only in a radiation field having substantially plane wave fronts.

Moreover, it has been found that, for optimum performance with radiation of a given wavelength λ , the dimensions of the plane grid should differ in a particular manner from the dimensions that would give optimum performance in a plane wave field of the same wavelength. The reasons for that difference in grid dimensions are not fully understood, and no method is known by which the results of the present invention could have been derived from previously available information.

For a cylindrical wave field of the type described, it has been discovered that cylindrical radiation of given wavelength, initially polarized linearly parallel to the axis of the radiation source, can be transformed effectively into circularly polarized radiation by a plane grid for which the width D of the vanes and the perpendicular spacing a between adjacent vanes are both greater than would be predicted on the basis of available experience with plane wave fields. Moreover, the most effective angle θ between the length of the grid vanes and the cylindrical wave axis has been found to be appreciably greater than the theoretical value of 45° .

When the dihedral angle of the cylindrical primary wave field is approximately 90° , a preferred combination of values of the above defined quantities has been found to give particularly effective performance. That combination, which is mentioned for purposes of illustration, comprises an angle θ of about 49° , and a vane width D about 25% greater, and a vane spacing a about 10% greater, than would give optimum performance in a plane wave field for radiation of the same wavelength.

A full understanding of the invention and of its further objects and advantages will be had from the following description of an illustrative preferred embodiment of the invention in an antenna system adapted for radar operation. The particulars of that description, and of the accompanying drawings which form a part of it, are intended as illustration only, and not as a limitation upon the scope of the invention, which is defined in the appended claims.

In the drawings:

Fig. 1 is a schematic perspective illustrating a polarization controlling grid in a plane radiation field;

Fig. 2 is a schematic perspective illustrating a cylindrical radiation field and a polarization controlling grid;

Fig. 3 is a schematic plan corresponding to Fig. 2;

Fig. 4 is a developed schematic section on the line 4—4 of Fig. 3;

Fig. 5 is a partly schematic plan representing an illustrative embodiment of the invention in a radar antenna system with vertical antenna array;

Fig. 6 is a fragmentary plan, corresponding to a portion of Fig. 5, at enlarged scale;

Fig. 7 is a fragmentary elevation in the aspect indicated by line 7—7 of Fig. 6;

Fig. 8 is a fragmentary elevation in the aspect indicated by line 8—8 of Fig. 6; and

Fig. 9 is a detail plan representing a modified form of vane with bracket portions not yet bent.

Fig. 1 represents schematically a radiation field having plane wave fronts normal to the direction of propagation 10. The wave field is initially linearly polarized vertically as indicated schematically by the arrow 11. A conventional plane grid for modifying that condition of polarization is represented at 12, positioned transversely of the radiation path 10. Polarizing grid 12 comprises a rectangular frame 13 and a plurality of elongated flat and relatively thin electrically conductive vanes 14 which extend in uniformly spaced parallel formation across the path of the radiation. The length of vanes 14 forms an oblique angle with the direction of polarization 11 of the radiation field.

The transverse dimension of the vanes is substantially perpendicular to the wave front, and hence parallel to the direction of propagation of the radiation. The radiation passes through the grid much as light is transmitted by a Venetian blind in open position. However, radiation polarized parallel to the vanes of the grid is transmitted at a higher phase velocity than radiation polarized perpendicular to the vanes. After passage through the grid, those two components of the primary radiation beam are therefore out of phase by a definite phase difference, determined by the dimensions of the grid. Since the grid vanes are oblique to the direction of polarization of the radiation incident upon them, that radiation may be considered to be made up of two components polarized parallel to and perpendicular to the vanes, respectively, and initially in phase. If the intensities of the parallel and perpendicular components of the radiation transmitted by the grid are equal, and if the phase difference between them is 90°, then linearly polarized radiation incident upon the grid is transformed by passage through it into circularly polarized radiation, as indicated at 15. Similarly, circularly polarized radiation is transformed by passage through grid 13 into linearly polarized radiation.

The ratio of the intensities of the parallel and perpendicular components entering the grid depends upon the effective degree of obliqueness of the inner vane edge with respect to the direction of polarization of the radiation. More exactly, that ratio depends upon the value of the oblique angle between the direction of linear polarization at any point of the incident wave front and the projection upon the wave front of the vane edge. The two incident components are equal when that angle is 45°. To produce a 90° phase difference between the two transmitted components, a definite theoretical relation must be satisfied between the separation a of adjacent vanes, the effective width D of the vanes and the wavelength emitted by the array. With respect to a grid for use in fully collimated radiation (plane wave front), that theoretical relation may be expressed in approximate form, neglecting, for example, end effects at the blade edges:

$$a = 2D \left(\frac{\lambda}{8D - \lambda} \right)^{1/2} \quad (1)$$

To produce a 90° phase difference while maintaining efficient matching for the parallel component, it is preferred

that the further approximate relation be effectively satisfied,

$$D = \frac{a\lambda}{(4a^2 - \lambda^2)^{1/2}} \quad (2)$$

Relations 1 and 2 reduce to the very simple form,

$$a = 2\lambda/3 \quad (3)$$

$$D = 3\lambda/4$$

Because of the so-called edge effect, which can be derived by more elaborate analysis, the vane width D which appears in those theoretical relations must be taken as the effective width of the vanes, as they appear to the radiation, rather than the actual physical dimension of the vanes. The difference between the effective and the actual vane width, and its effect upon the optimum spacing a , are known from experience with flat polarizing grids in radiation fields having plane wave fronts. For that type of service, optimum performance is obtained when the actual physical dimensions a' and D' , as distinct from the electrically effective dimensions a and D of Equations 1, 2 and 3, bear the following relation to the radiation wavelength λ :

$$a' = 0.654\lambda \quad (4)$$

$$D' = 0.608\lambda$$

However, the problem of modifying the condition of polarization of a cylindrical wave field is quite different from that presented by a radiation field having plane wave fronts. Figs. 2 and 3 represent in schematic form a linear radiation source 20, producing a radiation field 22 having cylindrical wave fronts, typically indicated by the surface 23, and initially polarized linearly in a direction parallel to the axis of source 20, as indicated by the arrow 24. As schematically represented, the radiation field 22 is limited (by means not shown) to the space bounded by a dihedral angle 26 having its apex in the axis 25 of source 20. That angle is shown typically as approximately 90°. A flat polarization grid, generally similar to grid 12 of Fig. 1, is represented at 30 in Figs. 2 to 4, with frame 32 and straight flat vanes 34 set in the frame at an oblique angle to the direction of linear polarization 24. It is evident, however, from the figures that a grid of that type cannot satisfy the theoretically necessary conditions just described for transforming linearly polarized to circularly polarized radiation.

Because of the cylindrical form of wave front 23, the plane of flat grid 30 is not even approximately parallel to the wave front except at its central portion as seen in Fig. 3. If the described theoretical conditions are approximately met for that central portion, they cannot be met for other parts of the wave field. That is shown particularly clearly in Fig. 4, which is a developed section taken on line 4—4 of Fig. 3. Fig. 4 may be considered to represent grid 30 as seen by the cylindrical wave front 23, the line of sight being at each point parallel to the direction of propagation, which is radial with respect to source 20. Grid vanes 34 appear to the radiation to be curved, so that if the angle θ between the vanes and the direction of polarization 24 is 45° at one part of the grid, it departs appreciably from 45° at other parts. It would therefore appear that a grid such as 30 might produce circularly polarized radiation in one part of the beam, but must produce only elliptically polarized radiation in other parts of the beam.

The curvature of vanes 34 as seen by the radiation also causes the apparent perpendicular spacing between adjacent vanes, as seen by the radiation, to vary over the area of the grid, that spacing being less near the sides of the grid than near the center. That apparent variation in vane spacing is associated with the fact, clearly represented in Fig. 4, that the radiation does not strike the vanes edge-on except at the central portion of the grid.

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Moreover, the effective width D of the vanes may be expected to vary over the area of the grid, being a minimum at the center where the direction of radiation propagation is perpendicular to the length of the vanes, and becoming progressively greater toward the sides of the grid, where the radiation passes obliquely across the plane of the grid, as seen best in Fig. 3. Hence, even if the dimensions a and D should be selected to give the required 90° phase difference and good impedance matching at one area of the grid, for example near the center, it would be expected that neither the phase difference nor the matching would be sufficiently accurate at other parts of the grid to give satisfactory performance.

However, it has been discovered that a radiation field having cylindrical wave fronts extending through a dihedral angle of 90° or more can be effectively transformed between linearly polarized and circularly polarized condition by means of a flat grid of the general type described. That is believed to be particularly true when the grid is placed relatively close to the cylindrical axis of the field, that is to say, within a distance that is of the same order of magnitude as the wavelength λ of the radiation. The effectiveness of a flat grid for the purpose described is also believed to be enhanced when collimating means, such as a cylindrical reflector (see below) is provided radially outward of the grid. For best performance, whether or not such additional conditions are satisfied, it has been found that the angle θ , already defined, should be appreciably larger than 45° . Also, the vane width D and the vane spacing a are preferably greater than the values that would give optimum performance in a plane wave field having the same wavelength.

As an illustrative example, when the dihedral angle of the cylindrical wave field is approximately 90° , particularly good performance has been obtained with a plane grid having a value of θ approximately 5° greater than the theoretical value of 45° , a typical value of θ being 49° ; and having values of a and D bearing the following typical relations to the radiation wavelength λ :

$$\begin{aligned} a &= 0.73\lambda \\ D &= 0.77\lambda \end{aligned} \quad (5)$$

By comparison with the optimum dimensions for plane waves given in Equations 4, the value of a given in Equation 5 is greater by about one tenth, and that of D is greater by about one quarter.

Figs. 5 to 8 represent an illustrative embodiment of the invention in a radar antenna system having a vertical linear array 40 of energy radiating elements 41. That array is representative of various types of known means for producing linearly polarized radiation in the form of a beam, typically indicated at 50, that is collimated in its coordinate parallel to the array axis and that is divergent in its coordinate transverse of the array axis. Radiating elements 41 are shown illustratively and somewhat schematically as aligned dipoles which project from the electrically conductive front face 44 of the elongated rectangular array housing 42. That housing typically encloses means for supplying energy of suitable predetermined frequency to the respective dipoles of the array in correlated amplitude and phase. Such linear arrays of radiating elements and means for powering and controlling them are well known in the art, and need not be described in detail. In the particular structure illustrated, the dipoles are so aligned that the radiation emitted by array 40 is initially linearly polarized substantially parallel to the longitudinal axis of the array. The plane of Fig. 5, for example, is transverse of that direction of polarization.

The divergence of primary beam 50 in the plane of Fig. 5 is clearly shown in the figure. The primary beam is confined within an effective angle of approximately 90°

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by reflection at front face 44 of array housing 42 and at the flat conductive face 46 of the reflecting fin 46a, which extends parallel to the array and closely spaced from it in a plane normal to the housing face. For purposes of the present description, the array of radiating elements 41 and the two reflective faces 44 and 46 may be considered to form a primary source of energy of known type from which the primary beam 50 is radiated. The effective axis of that energy source is midway between the array proper and its three virtual images 47, 48 and 49 formed in the dihedral reflector 44, 46 (Fig. 6). That effective axis of the radiation source is at the corner of the dihedral angle, as indicated at 51, and will be referred to as the axis of the source.

Primary radiation beam 50, which is divergent in its transverse coordinate, is intercepted and reflected by the cylindrical parabolic reflector 60, which is mounted with respect to array housing 42 by the brackets 62. That reflector is of a type that reflects radiation polarized both parallel and perpendicular to source axis 51. It is ordinarily preferred that those two components of the radiation be reflected with equal efficiency, and the reflector may then, for example, comprise a smooth electrically conductive reflecting face. The reflector is mounted with its focal axis parallel to, and coinciding with, source axis 51. Consequently the reflected secondary radiation beam, indicated at 52, is collimated in its transverse coordinate by the parabolic reflector, as clearly represented in Fig. 5. The initial collimation of the primary beam in its axial coordinate is not disturbed by the cylindrical reflector, and secondary beam 52 is therefore fully collimated (within the physical capacity of the equipment) and is suitable, for example, as a precision radar beam.

The linearly polarized radiation inherently emitted by linear array 40 may be transformed into circularly polarized radiation by inserting in divergent primary beam 50 a polarizing grid of suitable form in a position spaced relatively closely to array 40 and relatively widely from reflector 60. Such a polarizing grid in accordance with the present invention is indicated in illustrative preferred form at 70. It comprises a plurality of relatively thin electrically conductive vanes 72 between which the radiation passes. By virtue of passing through grid 70 the divergent linearly polarized beam is transformed into circularly polarized radiation, and that condition of polarization is not disturbed by subsequent reflection and collimation of the beam by reflector 60. Fully collimated beam 52 therefore consists of circularly polarized radiation. The sense of that polarization depends, in a manner to be described, upon the detailed structure of grid 70. For either sense of polarization, incoming radiation polarized in the same sense is caused by reflector 60 to converge upon grid 70 and is transformed by the grid into radiation linearly polarized in the same direction as radiation emitted by array 40. Such radiation is received by the array. Incoming radiation circularly polarized in the opposite sense is transformed by grid 70 into radiation linearly polarized normal to the direction of polarization of array 40, and the array is inherently insensitive to such radiation. Hence, the entire antenna system, with grid 70 in the position indicated, selectively emits only circularly polarized radiation of a predetermined sense, and responds fully to incoming radiation only if it is circularly polarized in that same sense.

Vanes 72 of polarizing grid 70 are rigidly mounted in uniformly spaced parallel relation by means of the frame members 74 and 75, which are preferably oblique to the plane of the grid, as shown clearly in Fig. 6, for example. Frame member 74 may be rigidly mounted directly on front face 44 of array housing 42 in any suitable manner, and frame member 75 may be mounted by brackets 76 on reflecting fin 47 in parallel relation to the

reflective face 46 of that fin. The two frame members then may act as extensions of the beam defining reflectors 44 and 46.

It is not necessary that the plane of the grid form equal angles with the two planes that effectively limit the angular extent of primary beam 50, which planes substantially coincide in the present instance with reflective surfaces 44 and 46. As illustrated, angle A between the plane of the grid and face 44 of the array housing is about 38° , and the angle B between that plane and fin surface 46 is about 52° .

The individual vanes 72 may be formed from a single piece 79 of electrically conductive sheet material, shaped typically as indicated in Fig. 9. The two end portions 77 and 78 are then bent in opposite directions through suitable oblique angles about the respective lines 81 and 82 to form supporting brackets for the vane, lying parallel to and adapted to be directly secured to the respective frame members 74 and 75.

The entire grid is preferably readily shiftable to inoperative position to permit normal linearly polarized operation of the antenna system. Such shifting may be accomplished simply by detaching frame members 74 and 75 from array housing 72, but it is preferred to provide remotely controllable means for shifting the grid to a definite idle position outside of both primary and secondary radiation beams 50 and 52. Such means may be of the type described and claimed in our copending patent application, Serial No. 361,144, filed June 12, 1953, under the title "Circularly Polarized Directional Antenna System."

Fig. 9 illustrates a further aspect of the present invention, whereby the physical width of the vanes of a polarization grid for the present purpose is a maximum near the center and decreases progressively toward the ends in a manner to provide a substantially constant effective vane width in the direction of radiation propagation. That may be accomplished by convex curvature of either outer vane edge 85, as illustratively shown, or of inner vane edge 84. Or, both edges may be curved with curvatures that are related in a manner to provide the desired degree of taper toward the ends of the vanes. Whereas the provision of such controlled taper of the width of flat vanes in a polarization grid for use in connection with a cylindrical radiation field comprises one aspect of the present invention, entirely satisfactory performance may well be obtainable with flat vanes of uniform width, as illustrated, for example, in Fig. 6.

As an illustrative example of performance obtainable with an antenna assembly of the type represented in Figs. 6 to 8, the following data have been obtained for a radar system intended specifically for a ground controlled approach (GCA) system for aircraft. In that system separate antenna assemblies of the general type shown are employed for scanning in elevation and in azimuth, the drawings relating more particularly to the elevation system. Scanning in those antenna assemblies is accomplished in known manner by suitable control of the relative phasing of the radio frequency energy supplied to the respective antenna elements 41, the beam being thereby caused to swing in a plane through the antenna axis through effective scanning angles of approximately 7° for the elevation antenna and 20° for the azimuth antenna, the radiated beam being in each instance approximately perpendicular to the axis of the antenna array at one extreme of the scanning range. Because of that scanning movement, the wave front of the resulting radiation is typically not strictly cylindrical, but is somewhat conical in form, the apex angle of the cone corresponding to the scanning angle of the beam. The term "cylindrical" is employed herein in the sense of including such moderately conical forms of wave front.

In the present illustrative system both antenna systems operate at an optimum frequency of 9080 megacycles per second, corresponding to a radiation wavelength λ of

about 1.300 inches. Highly satisfactory polarization characteristics can be obtained in secondary beam 52 with plane grid structure of the type described having the spacing a between adjacent vanes substantially one tenth greater, and the vane width D substantially one quarter greater than the corresponding values, given in Equations 4 above, that would lead to optimum performance in a plane wave field. The degree of ellipticity in the final radar beam in such a system has been found to be typically less than one decibel, in terms of the ratio of the axes of the ellipticity, that observed value corresponding to 20 to 25 decibels of attenuation of rain clutter relative to normal target signals. Not only is that degree of ellipticity remarkably slight, considering the effects discussed above in connection with Fig. 4; but it has been found to be affected very little, if at all, by the described scanning movements of the radar beams.

We claim:

1. A grid for controlling the condition of polarization of electromagnetic radiation having substantially cylindrical wave fronts and having a predetermined wavelength λ , said grid comprising a plurality of flat elongated vanes of electrically conductive material arranged in respective uniformly spaced mutually parallel planes that form equal oblique angles with the cylindrical axis of the wave fronts, the width of the vanes being greater by approximately one quarter than the value 0.608λ , which value would produce substantially optimum performance in a radiation field having plane wave fronts and having the same wavelength λ .

2. A grid for controlling the condition of polarization of electromagnetic radiation having substantially cylindrical wave fronts and having a predetermined wavelength λ , said grid comprising a plurality of flat elongated vanes of electrically conductive material arranged in respective uniformly spaced mutually parallel planes that form equal oblique angles with the cylindrical axis of the wave fronts, the perpendicular spacing between adjacent vanes being greater by approximately one tenth than the value 0.654λ , which value would produce substantially optimum performance in a radiation field having plane wave fronts and having the same wavelength λ .

3. A grid for controlling the condition of polarization of electromagnetic radiation having substantially cylindrical wave fronts and having a predetermined wavelength λ , said grid comprising a plurality of flat elongated vanes of electrically conductive material arranged in respective uniformly spaced mutually parallel planes, the width of the vanes and the spacing between adjacent vanes being greater than the respective values 0.608λ and 0.654λ , which values would produce substantially optimum performance in a radiation field having plane wave fronts and having the same wavelength λ , and means for supporting the grid with the vanes forming equal oblique angles with the cylindrical axis of the wave fronts, said angles being greater than 45° and being approximately equal to 50° , the plane of the grid being substantially parallel to that axis and spaced therefrom by a distance of the same order of magnitude as λ .

4. In combination with an antenna assembly comprising two substantially plane radiation reflectors mounted in respective planes that form a dihedral angle of approximately 90° , a linear radiation source adapted to produce an electromagnetic radiation field having substantially cylindrical wave fronts linearly polarized parallel to the source axis and having a predetermined wavelength λ , and means supporting the source in substantially parallel relation with the said reflectors within the dihedral angle; a polarization controlling grid for transforming the radiation field of the antenna assembly from linearly to substantially circularly polarized condition, said grid comprising a plurality of flat elongated vanes of electrically conductive material arranged in respective uniformly spaced mutually parallel planes that form equal oblique angles with the source axis, said vanes extending substan-

tially between the planes of the reflectors radially outside of the source, the width of the vanes and the perpendicular distance between the planes of the vanes being greater than the respective values of 0.608λ and 0.654λ , which values would produce substantially optimum performance in an electromagnetic radiation field having plane wave fronts and having the same wavelength λ .

5. In combination with an antenna assembly comprising two substantially plane radiation reflectors mounted in respective planes that form a dihedral angle of approximately 90° , a linear radiation source adapted to produce an electromagnetic radiation field having substantially cylindrical wave fronts linearly polarized parallel to the source axis and having a predetermined wavelength λ , and means supporting the source in substantially parallel relation with the said reflectors within the dihedral angle; a polarization controlling grid for transforming the radiation field of the antenna assembly from linearly to substantially circularly polarized condition, said grid comprising a plurality of flat elongated vanes of electrically conductive material arranged in respective uniformly spaced mutually parallel planes that form equal oblique angles with the source axis, said vanes extending substantially between the planes of the reflectors radially outside of the source, the oblique angles between the array axis and the planes of the respective vanes being greater than 45° and being approximately equal to 50° .

6. In combination with an antenna assembly comprising two substantially plane radiation reflectors mounted in respective planes that form a dihedral angle of approximately 90° , a linear radiation source adapted to produce an electromagnetic radiation field having substantially cylindrical wave fronts linearly polarized parallel to the source axis and having a predetermined wavelength λ , and means supporting the source in substantially parallel relation with the said reflectors within the dihedral angle; a polarization controlling grid for transforming the radiation field of the antenna assembly from linearly to substantially circularly polarized condition, said grid com-

prising a plurality of flat elongated vanes of electrically conductive material arranged in respective uniformly spaced mutually parallel planes that form equal oblique angles with the source axis, said vanes extending substantially between the planes of the reflectors radially outside of the source, the perpendicular distance between the planes of the respective vanes being approximately 0.73λ , and the width of the vanes being approximately 0.77λ .

7. An antenna assembly for producing a directed beam of substantially circularly polarized electromagnetic radiation, said antenna assembly comprising linear antenna means for producing a radiation field having substantially cylindrical wave fronts of predetermined wavelength λ linearly polarized parallel to the axis of the antenna means and limited substantially to a dihedral angle of approximately 90° about that axis, a polarization controlling grid for transforming the radiation field of the antenna assembly from linearly to substantially circularly polarized condition, said grid comprising a plurality of flat elongated vanes of electrically conductive material arranged in respective uniformly spaced mutually parallel planes that form equal oblique angles with the source axis, said vanes extending substantially between the sides of the said dihedral angle radially outside of the source, and a cylindrical reflector mounted radially outside of said grid with its focal axis substantially coinciding with the axis of the antenna means, the width of the vanes and the perpendicular distance between the planes of the vanes being greater than the respective values of 0.608λ and 0.654λ , which values would produce substantially optimum performance in an electromagnetic radiation field having plane wave fronts and having the same wavelength λ .

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