May 8, 1956 J. G. McCANN ET AL 2,745,100

CIRCULARLY POLARIZING DIRECTIONAL ANTENNA SYSTEM

Filed June 12, 1953 3 Sheets-Sheet 1

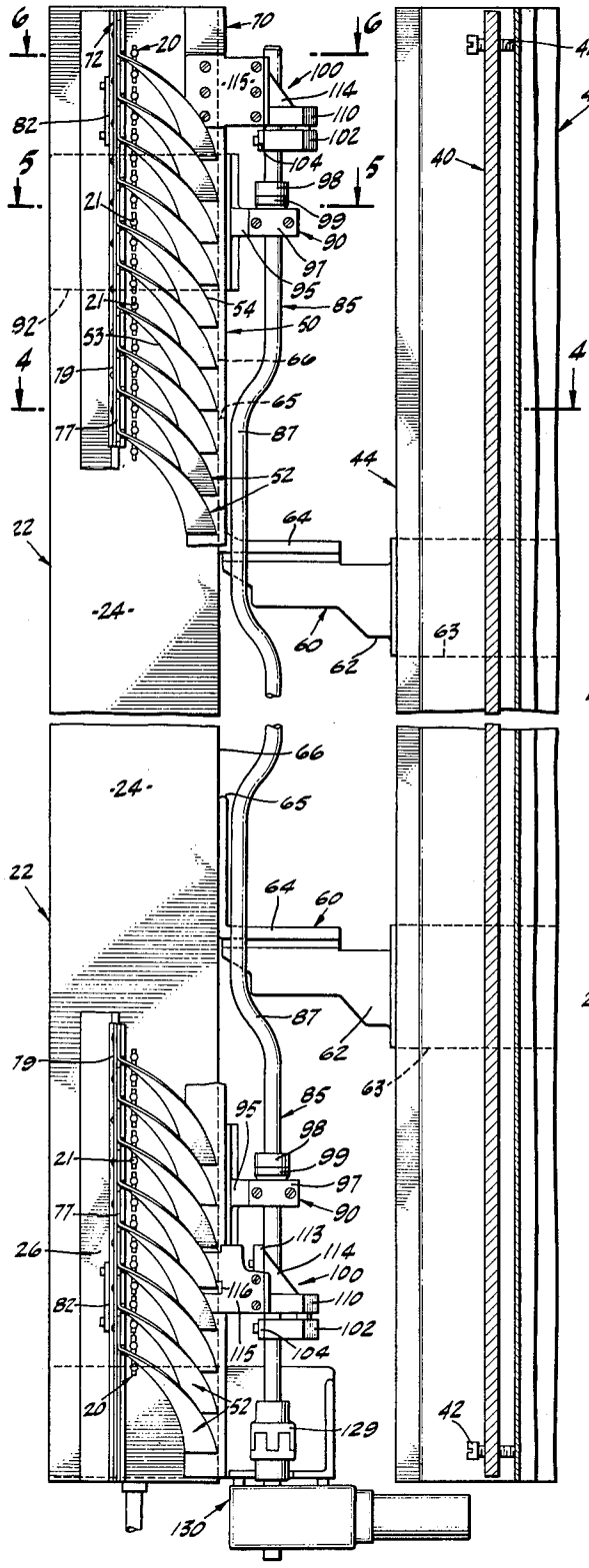


FIG. 1.

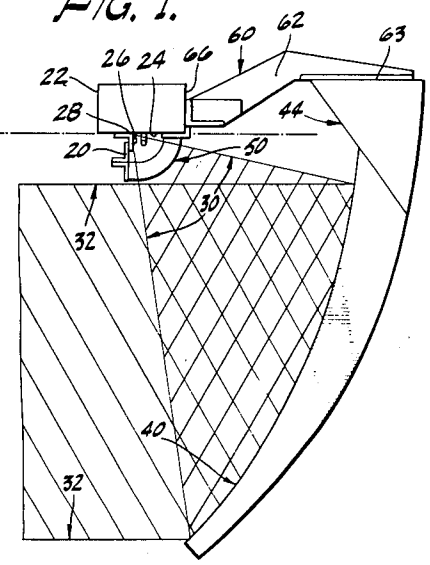


FIG. 3.

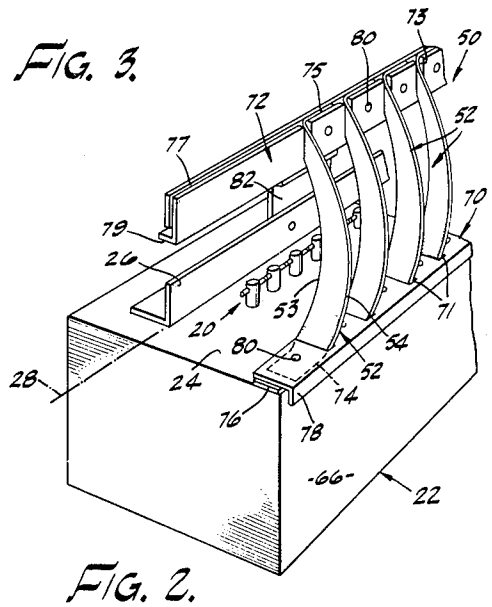


FIG. 2.

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CIRCULARLY POLARIZING DIRECTIONAL ANTENNA SYSTEM

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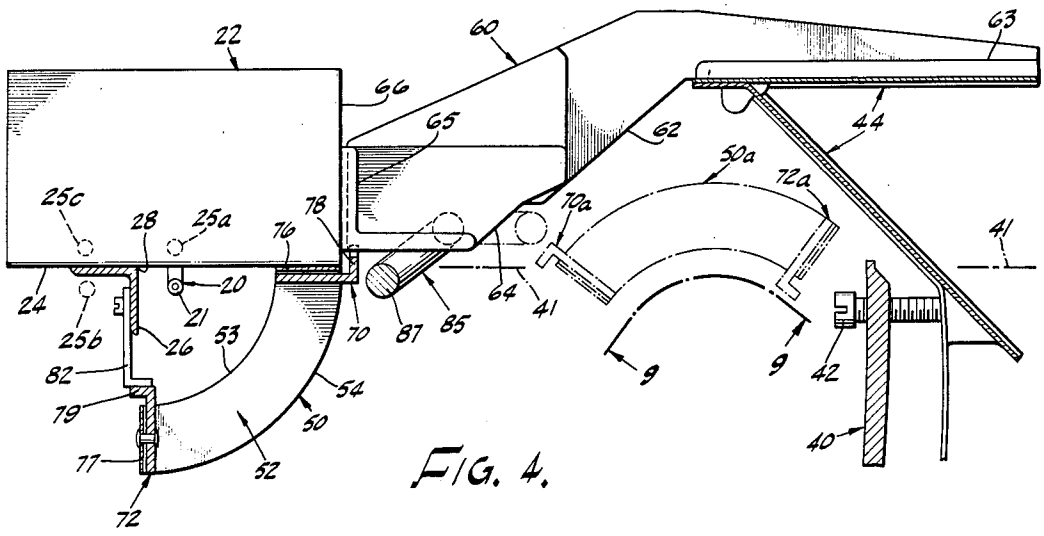


FIG. 4.

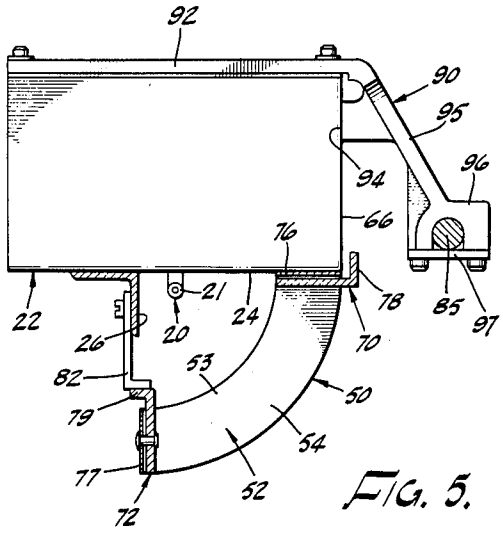
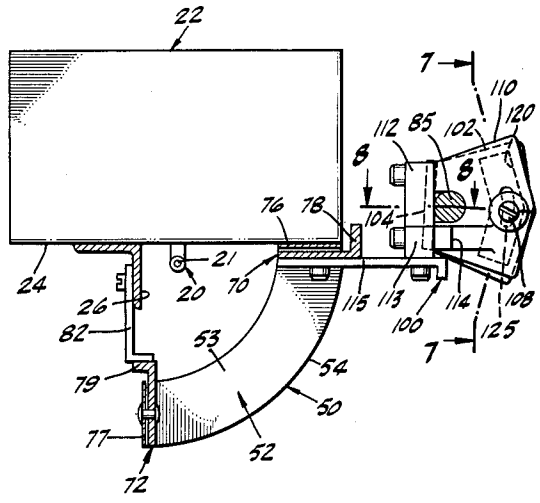


FIG. 5.

FIG. 6.



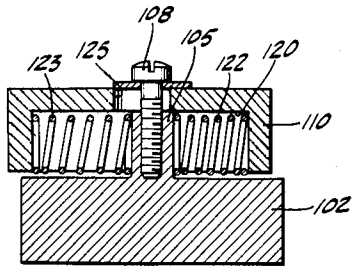


FIG. 7.

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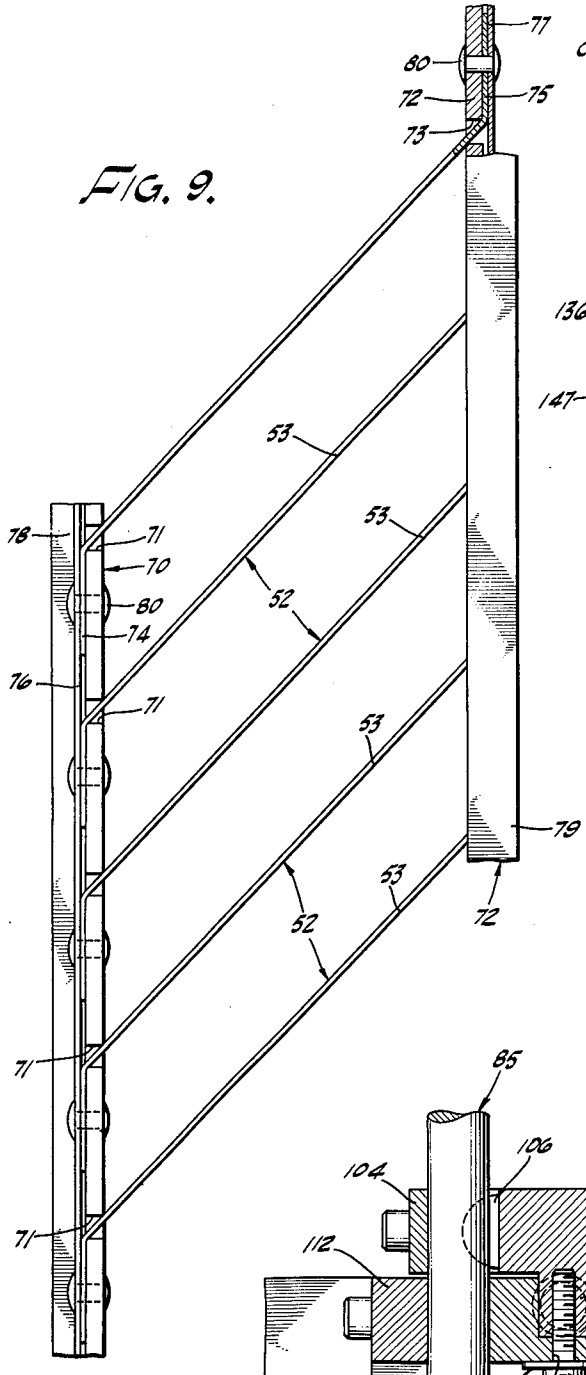
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CIRCULARLY POLARIZING DIRECTIONAL ANTENNA SYSTEM

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FIG. 9.



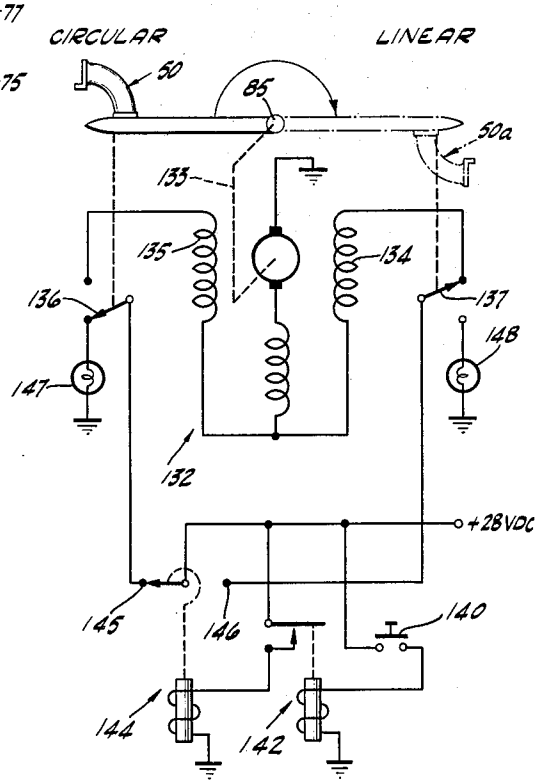
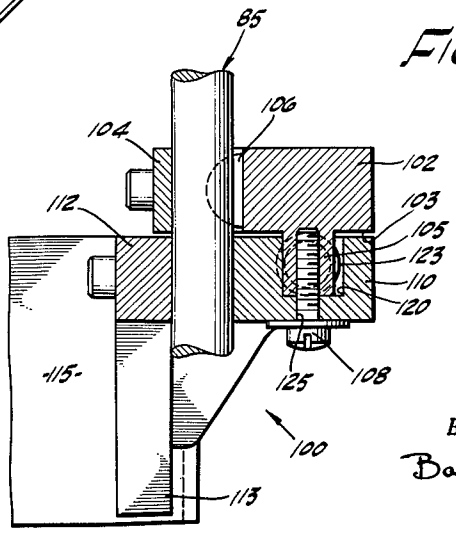


FIG. 10.

FIG. 8.



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2,745,100

CIRCULARLY POLARIZING DIRECTIONAL ANTENNA SYSTEM

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Application June 12, 1953, Serial No. 361,144

5 Claims. (Cl. 343—756)

This invention is concerned generally with antenna means for producing or receiving electromagnetic radiation having predetermined polarization characteristics. The present application is a continuation in part of our copending application Serial No. 339,988, filed March 3, 1953, and now abandoned.

More particularly, the invention has to do with directional antenna means effective within a narrowly limited angular range. Antenna means of that type are widely used, for example, for emitting sharply directional radar beams and for receiving reflected radar signals from a limited angle in space and with relatively high effective gain. An important object of the invention is the provision of particularly simple directional antenna means capable of emitting and receiving circularly polarized radiation.

A further object of the invention is to provide directional antenna means capable of producing selectively either circularly polarized radiation or linearly polarized radiation. Moreover, in accordance with the invention it is possible to shift from one type of radiation to the other reliably and rapidly, so that the shift can be made without appreciable interruption of the service of the equipment.

The invention is particularly valuable in connection with antenna systems of the type that utilize a linear array of primary energy radiating elements together with a cylindrical reflector, the linear array producing collimation of the emitted primary radiation beam in one coordinate, and the reflector producing collimation of the reflected secondary beam in the other coordinate. Antenna means of that type are used, for example, in radar systems, and particularly in systems for controlling from the ground the approach and landing of aircraft. Since such systems are often required to be readily portable, particularly for military use, compact construction and light weight are primary requirements.

It is known that the use of circularly polarized radiation may be highly advantageous in radar systems. In particular, circular polarization may largely overcome the tendency of rain in the path of the radar beam to produce excessive clutter on the radar screen and to reduce visibility of targets. If the radar antenna system is so constructed as to emit only circularly polarized radiation of one sense of rotation, for example right-handed, it will also receive only circularly polarized radiation of the same sense of rotation. Rain tends to reflect right-circular polarization as left-circular polarization. Therefore the reflected circularly polarized radiation from the rain is not received by such an antenna and hence does not appear as clutter on the radar scope. Reflection from normal targets, on the other hand, typically comprises a mixture of right- and left-circular polarization, and the right-handed component is received normally. Thus, although the effective intensity of the reflected beam may be considerably reduced, that of the rain clutter is virtually eliminated, and targets are therefore visible even in the presence of heavy rain.

In spite of that potential utility of radar antenna systems adapted to emit and receive only circularly polarized radiation, such antenna systems employing large linear arrays as primary radiators have previously been so cumbersome as to be impractical. Moreover, no satisfactory means was available for switching easily and rapidly from circular polarization to normal operation of the antenna system. The present invention solves that problem and provides a compact, rugged and convenient mechanism that can be converted from normal operation to circular polarization in only a few seconds.

That is accomplished in antenna systems of the type described by providing a circular polarizing grid in the primary radiation beam between the linear antenna array and the cylindrical reflector. That placement is such that the grid intercepts substantially the whole of the primary radiation beam, but is substantially wholly outside of the secondary beam reflected from the cylindrical reflector. It has been discovered that a circular polarizing grid can effectively be so positioned in the primary beam and outside of the secondary beam.

A particular advantage of that arrangement is that the polarizing grid may be placed relatively close to the antenna array, where the transverse cross section of the beam is relatively narrow. The condition of polarization of the entire beam can therefore be controlled by a grid of compact form and light weight. It has been found that such a polarizing grid can be so mounted as to be selectively shiftable to a stowed or idle position outside of both primary and secondary beams. A preferred location for that idle position is between the array and the reflector and substantially in the axial plane of the latter.

The invention further provides a circular polarizing grid of novel form, which is particularly well adapted for use in the primary beam from a linear antenna array. The form of that grid is such that it presents identically uniform structure to all portions of the wave front, regardless of the fact that the primary radiation beam is collimated in one coordinate and is divergent in the other coordinate, and hence has a cylindrical or conical wave front.

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 partly schematic plan of an illustrative embodiment of the invention in a radar antenna system with vertical linear antenna array;

Fig. 2 is a fragmentary perspective illustrating a preferred type of grid structure;

Fig. 3 is an elevation, partly broken away, of an illustrative embodiment of the invention;

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

Fig. 5 is a section on line 5—5 of Fig. 3;

Fig. 6 is a section on line 6—6 of Fig. 3;

Fig. 7 is a section on line 7—7 of Fig. 6;

Fig. 8 is a section on line 8—8 of Fig. 7;

Fig. 9 is a developed section on line 9—9 of Fig. 4, at enlarged scale and illustrating a preferred manner of construction; and

Fig. 10 is a schematic diagram of an illustrative electric circuit for controlling the condition of the antenna system.

The antenna system of the figures includes a vertical linear array 20 of energy-radiating elements 21, which

is intended to be representative of various types of known means for producing linearly polarized radiation in the form of a beam, typically indicated at **30**, 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 **21** are shown illustratively as aligned dipoles which project from the electrically conductive front face **24** of the elongated rectangular array housing **22**. 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 **20** is then linearly polarized substantially parallel to the longitudinal axis of the array. The plane of Fig. 1, for example, is transverse of that direction of polarization.

The divergence of primary beam **30** in the plane of Fig. 1 is clearly shown in the figure. The primary beam is confined within an effective angle of substantially 90° by reflection at front face **24** of array housing **22** and at the flat conductive face of reflecting fin **26**, 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 **20** and the two reflective faces **24** and **26** may be considered to form a primary source of energy of known type from which the primary beam **30** is radiated. The effective axis of that energy source is midway between the array proper and its three virtual images **25***a*, **25***b* and **25***c* formed in the dihedral reflector **24**, **26** (Fig. 4). That effective axis of the radiation source is at the corner of the dihedral angle, as indicated at **28**, and will be referred to as the axis of the array.

Primary radiation beam **30**, which is divergent in its transverse coordinate, is intercepted and reflected by the cylindrical parabolic reflector **40**. That reflector is of a type that reflects radiation polarized both parallel and perpendicular to the length of array **20**. 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 **28**. Consequently the reflected secondary radiation beam, indicated at **32**, is collimated in its transverse coordinate by the parabolic reflector, as clearly represented in Fig. 1. The initial collimation of the primary beam in its axial coordinate is not disturbed by the cylindrical reflector, and secondary beam **32** is therefore fully collimated (within the physical capacity of the equipment) and is suitable, for example, as a precision radar beam.

As illustrated, reflector **40** is an off-axis parabola, with axial plane at **41**, permitting array housing **22** to be located entirely outside of the secondary beam. Whereas that arrangement is preferred, it is well known that a radiation beam of the type represented by beam **30** may alternatively be collimated by a cylindrical reflector of symmetrical parabolic type. With either type of reflector the production of an accurately collimated secondary beam demands that the dimensions of the reflector be large compared to the wave length of the radiation. That is particularly true when, as in the present illustrative instance, the effective origin of the radiation includes virtual images **25** as well as the actual energy-emitting elements of array **20**. Hence the cross sectional area of secondary beam **32** is necessarily quite large, and any means that might be inserted in that beam to alter its condition of polarization would necessarily be cumbersome, inconvenient and expensive.

In accordance with the invention, a fully collimated beam of circularly polarized radiation can be produced from a linear source of the type described without the need of altering the condition of polarization of the collimated secondary beam itself. It has been discovered that the fact that the primary beam is collimated only in one coordinate and is sharply divergent in the other coordinate, does not prevent effective transformation of its condition of polarization. On the contrary, the divergence of the beam, far from preventing control of its polarization, makes possible such control with polarizing means of remarkably compact form and light weight. The linearly polarized radiation inherently emitted by linear array **20** is transformed into circularly polarized radiation by inserting in divergent primary beam **30** a polarizing grid of suitable form in a position spaced relatively closely to array **20** and relatively widely from reflector **40**. Such a polarizing grid is indicated in illustrative preferred form at **50**. It comprises a plurality of relatively thin electrically conductive vanes between which the radiation passes. By virtue of passing through grid **50** 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 **40**. Fully collimated beam **32** therefore consists of circularly polarized radiation. The sense of that polarization depends, in a manner to be described, upon the detailed structure of grid **50**. For either sense of polarization, incoming radiation polarized in the same sense is caused by reflector **40** to converge upon grid **50** and is transformed by the grid into radiation linearly polarized in the same direction as radiation emitted by array **20**. Such radiation is received by the array. Incoming radiation circularly polarized in the opposite sense is transformed by grid **50** into radiation linearly polarized normal to the direction of polarization of array **20**, and the array is inherently insensitive to such radiation. Hence, the entire antenna system, with grid **50** in the position indicated, selectively emits only circularly polarized radiation of a predetermined sense, and responds to incoming radiation only if it contains circularly polarized radiation of that same sense.

Figs. 2 to 10 illustrate in detail a typical preferred embodiment of the invention. Reflector **40**, shown partly schematically, is mounted rigidly, but preferably adjustably, with respect to the main frame structure **44**, only a portion of which is shown in the drawings. Array housing **22** is rigidly supported with respect to frame **44** by a plurality of relatively heavy brackets **60**. As illustratively shown, those brackets comprise a support portion **62** that is rigidly mounted by means of the mounting pad **63** on the rear face of frame structure **44**; and an outer portion **64** that may be adjustably related to support portion **62** by means not shown in detail, and upon which array housing **22** is rigidly mounted. Array housing **22** typically comprises an assembly of relatively heavy and accurately formed aluminum members having the exterior form of an elongated rectangular box. Offset defining pads **65** of outer bracket portions **64** engage and are secured to inner side wall **66** of array housing **22**. The housing is thereby supported with its front face **24** in axial plane **41** of reflector **40**.

The individual radiating elements of array **20** are illustratively shown as the dipoles **21** which may be of conventional construction and are shown somewhat schematically. As shown, those elements are aligned in closely spaced formation along a straight line closely spaced from the front face **24** of array housing **22**. The longitudinal reflecting fin **26** is rigidly mounted normal to that face and closely spaced outwardly of the array of radiating elements. Reflection of the latter in housing face **24** and in the flat face of fin **26** produces the primary virtual images **25***a* and **25***b*, respectively, while successive reflection in those two faces produces a secondary virtual image **25***c* (Fig. 4). The geometrical center of those three linear images and of the array of radiating elements defines an effective array axis **28** that lies in the vertex of the dihedral angle formed by the

reflecting faces **24** and **26**. That axis **28** represents the effective axis of the antenna array, and the radiation can for many purposes be considered to emanate from it. As has already been indicated, the array housing is preferably so mounted with respect to reflector **40** that array axis **28** coincides with the focal axis of the reflector.

Polarizing grid **50** comprises a plurality of elongated and relatively thin electrically conductive vanes **52**, which extend in uniformly spaced parallel formation across the path of primary beam **30** at an oblique angle to the direction of its linear polarization. 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. It has been discovered that those two conditions can be effectively met, even for a radiation beam having a cylindrical or conical wave front (collimated in only one coordinate). It is therefore possible for the first time to control the condition of polarization of a fully collimated beam by operating upon the divergent and relatively compact primary beam from which it is produced.

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°. However, the efficiency of transmission of the two components through the grid may not be the same; and the two components may further be reflected with different efficiencies by reflector **40**. In order to compensate any such overall difference of transmission, reflection and the like, it is ordinarily preferred that the described oblique angle differ from 45° in a direction to favor the more attenuated component, thereby leading to equal amplitudes of the parallel and perpendicular components actually emitted by the entire assembly. In accordance with the invention, the grid is so constructed that the described oblique angle has a substantially uniform value over the whole of the cross section of the incident cylindrical or conical wave front.

To produce a 90° phase difference between the two transmitted components, a definite relation must be satisfied between the separation a of adjacent vanes, the effective width D of the vanes and the wavelength L emitted by the array. With respect to a grid for use in fully collimated radiation (plane wave front), that relation may be expressed in approximate form, neglecting, for example, end effects at the blade edges:

$$\frac{L}{a^2}=\frac{8D-L}{4D^2} \qquad (1)$$

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,

$$2D=\frac{L}{\sqrt{1-\left(\frac{L}{2a}\right)^2}} \qquad (2)$$

Relations (1) and (2) reduce to the very simple form,

$$a=0.67\,L$$
$$D=0.75\,L$$

Further in accordance with the present invention, the approximate relations (1) and (2) can effectively be applied also to a grid for use in radiation of the type described, collimated in only on coordinate (cylindrical or conical wave front), but the vane width is then measured (at any longitudinal position of the vale) in the plane through the array axis rather than normal to the vane edge. (It will be understood that those two manners of measurement may, under special conditions of blade form or of position of measurement, lead to the same value.) The grid is so constructed that the vane width, measured as just described in an axial plane, is substantially uniform over the entire effective area of the grid, and effectively satisfies relations (1) and (2).

An illustrative type of grid that satisfies the described conditions and is particularly satisfactory for the described purpose is illustrated in the drawings. Whereas that type of grid is presently preferred as to both form and structure, it is not intended that the scope of the invention be limited to such particular type. As illustrated, each of the vanes **52** is so formed and mounted (in operating position) as to lie in a helical surface about source axis **28**, the inner and outer longitudinal edges **53** and **54** of the vanes forming segments of helices about that axis of different radius but of equal pitch. The pitch of the vanes is such that the helix angle of helical inner edge **53** is typically approximately 45°; the helix angle of outer edge **54** is somewhat less, due to its greater radius. The different helix angles of the two vane edges results in a longitudinal twist of the fully formed vane, as is clearly indicated, for example, in Figs. 2 and 3. The edges of the untwisted vanes lie on circular concentric curves, the radii of which are greater than the corresponding radii of the helices they will form when twisted, the exact relation of the radii depending geometrically upon the precise helix angles of the twisted vanes.

A particular advantage of the preferred helical form of the individual vanes of the grid is the uniformity of its effect upon the radiation over the entire cross section of the primary beam. That advantage is well illustrated by the developed section of Fig. 9. That figure may be thought of as showing a portion of the grid as it would be seen by the incident radiation of divergent primary beam **30**. The effective uniformity of the grid structure as so seen by the radiation is clearly represented in the figure. Because of that effective uniformity inherent in the helical form of grid, the oblique angle between the inner blade edge and the direction of polarization is uniform over the whole grid, and is given a value approximating 45° and such as to compensate any difference of attenuation of the two components in the manner already described. Furthermore, with the preferred helical form of grid, the blade width D measured in an axial plane equals the width as usually measured normal to the vane edge. The width as ordinarily measured is therefore uniform over the entire length of the blades, enhancing the simplicity and economy of the structure.

The grid shown illustratively in the figures is such as to transform radiation polarized linearly parallel to array axis **28** into left-circular polarization, in which the electric vector may be considered to be of constant magnitude and to rotate counterclockwise when viewed along the direction of propagation. A similar grid having vanes extending obliquely with respect to the direction of initial

polarization, but in the opposite sense, that is, substantially perpendicular to the direction of vanes **52**, will produce right-circular polarization.

Whether the vane shape is of the preferred helical type described or not, the vanes may conveniently be mounted by securing their ends to longitudinal grid frame members, shown illustratively at **70** and **72**, respectively. Upper and lower end frame pieces may be provided if desired, rigidly joining the adjacent ends of the members **70** and **72** and forming an elongated rectangular frame. However, no such end pieces are shown, since vanes **52** ordinarily provide a sufficiently rigid relation between the side members. The latter will be spoken of as forming a frame even when no end frame pieces are used. Frame members **70** and **72** comprise essentially flat strips which are somewhat wider than the vanes **52** and which lie in radial planes with respect to the array axis **23**. The frame members are deeply transversely slotted in a radial direction at **71** and **73**, respectively, to receive the several vanes **52**, each of which typically consists of metal having a high electrical conductivity and is in the form of a sheet that is either continuous or of sufficiently fine structure to be effectively continuous. The vane ends, after passing through those slots, are bent sharply and then lie flatly against the back face of the members, as shown at **74** and **75**, where they are rigidly held by elongated keeper plates **76** and **77**, respectively, and by rivets **80** or the like. Reinforcing flanges are preferably provided on the frame member **70** and **72**. As shown, member **70** is thus reinforced along its radially outer edge by the flange **78** and member **72** is similarly reinforced along its inner edge by the flange **79**.

In operating position of grid **50**, shown in solid lines in the drawings, grid frame member **70**, or, more accurately, its keeper plate **76**, rests flatly on front face **24** of array housing **22**, while grid frame member **72** is supported in spaced relation to that housing, as by the brackets **82**. Those brackets may conveniently be mounted on the back face of reflecting fin **26**. If the antenna system is always required to be in circularly polarizing condition, grid **50** may be rigidly mounted in that position, as indicated schematically in Fig. 1.

However, in accordance with a further aspect of the invention, the polarizing grid is so mounted that it is readily shiftable between such an operating position as that just described and an idle position in which it is substantially or wholly clear of both primary and secondary radiation beams. Figs. 3 to 10 show illustrative means for shifting the grid in that manner. Whereas that typical means, which involves swinging movement of the grid about an axis, is preferred, the shifting movement of the grid is not necessarily of that type.

In the present illustrative embodiment, a shaft **85** is journaled with respect to array housing **22** by the shaft brackets **90**. As shown best in Figs. 3 and 5, brackets **90** include a large flat pad **92** adapted to be bolted to the rear face of array housing **22**, and a defining boss **94** adapted to engage inner face **66** of the housing. A bracket arm **95** supports the journal formation **96**, which comprises a recess for shaft **85** and a confining cover plate **97**. The longitudinal position of the shaft is defined with respect to brackets **90** as by the collars **98** and thrust bearings **99**. The shaft is thereby journaled on a shaft axis between array housing **22** and reflector **40** and slightly back of the plane of front face **24** of the housing, which is also the axial plane **41** of the reflector. In the particular arrangement illustrated, the shaft axis passes through the forward portion of brackets **60**, which support array housing **22** with respect to frame structure **44**. The shaft is offset in the neighborhood of those brackets, as indicated at **84**, to prevent interference with the brackets within the required angular range of its movement.

The polarizing grid **50** is mounted on shaft **85** in any suitable manner for swinging movement about the shaft axis. The preferred mounting means illustrated is particularly advantageous in that it defines rigidly the radial position of the grid with respect to the shaft and defines a definite range of angular positions within which a normal angular position is resiliently urged but not rigidly maintained. In the illustrative form shown, the grid is supported with respect to shaft **85** by a plurality of bracket assemblies **100**. Each bracket assembly **100** includes an anchor member **102**, which is fixedly mounted on shaft **85** as by the clamping plate **104** and the key **106** (Fig. 8); and a bracket member **110** upon which the grid is fixedly supported by the bracket plate **115**. Bracket member **110** is rotatably mounted on shaft **85**, as by a journal recess and a cover plate **112** that confines the shaft within the recess without clamping it. Cover plate **112** carries an arm **113** that extends longitudinally of shaft **85** and is supported by a web **114** on member **110**. Arm **113** provides a longitudinal side face to which the bracket plate **115** is fixedly mounted (Figs. 6 and 8). Bracket plate **115** is bolted directly to the face of grid frame member **70**, being slotted at **116** as may be required to clear grid vanes **52**.

The rotational position on shaft **85** of bracket member **110** is resiliently related to that of anchor member **102** by the typical means now to be described. A generally circumferential recess **120** in bracket member **110** contains two coil springs **122** and **123**, which are retained in the recess by the adjacent axial face **103** of anchor member **102** (Fig. 8). The latter member carries a post **105** that lies between, and is yieldingly positioned by, the adjacent opposed ends of springs **122** and **123**. Members **102** and **110** may be retained in correct relation longitudinally of shaft **85** by the screw **108**, which is received by a circumferentially elongated slot **125** in bracket member **110** and is threaded into the end of post **105**. The length of slot **125** permits relative rotational movement of members **102** and **110** within a definite angular range, and cooperates with screw **108** to provide a positive stop at the limits of that range. Within that limited range, springs **122** and **123** yieldingly urge the members toward an equilibrium rotational relation, typically such that the springs are of equal length.

As shown, particularly in Figs. 6 and 7, shaft **85** and anchor member **102** are in such rotational position as to compress spring **122** more than spring **123**, thereby yieldingly exerting a clockwise torque upon bracket member **110** and hence upon the entire polarizing grid. The grid is thereby yieldingly urged into accurately defined position against positive stops. Such a stop may be provided by the forward edge of plate **82**, which is fixedly, and preferably adjustably, mounted on reflecting fin **26** in position to engage flange **79** of grid frame member **72**. A stop formation such as plate **82** is preferably provided adjacent each of the respective grid bracket assemblies **100**, so that the torque exerted by the latter upon the grid frame is in each instance taken up by a stop directly opposite the point of its application, thereby minimizing distortion of the grid frame. Alternatively, for example, stops **82** may comprise a single continuous member extending substantially the entire length of the array. As illustrated, the other grid frame member **70** may also be positioned by abutting front face **24** of array housing **22**.

With the described illustrative structure, the polarizing grid may be shifted out of operating position by rotation of shaft **85** through a definite predetermined angle. As seen in Figs. 4–6, for example, that rotation is counterclockwise, and is somewhat less than 180°. The grid is thereby shifted to an idle position, typically shown in phantom lines at **50***a* in Fig. 4. In that idle position, the grid is between array **20** and cylindrical reflector **40**, closely adjacent the latter, and lies close to axial plane **41** of the reflector. The preferred idle position is substantially back of that plane (above it as seen in Fig. 4), so that no appreciable part of the grid or its supporting

structure extends into the radiation field of the antenna system. That radiation field, including both primary and secondary beams **30** and **32**, is somewhat spaced from axial plane **41** because of the shielding action of reflecting fin **26**, which necessarily extends somewhat forward of that plane. Positive stops may be provided to define accurately a definite idle position such as **50***a*. However, since that position is ordinarily not critical, no such stops are usually required.

Illustrative means are indicated at **130**, linked to shaft **85** by the coupling means **129**, for selectively shifting the grid between operating and idle positions. The means **130** may be considered to represent schematically any suitable mechanism for manually rotating the shaft selectively between its two positions. Alternatively, and in preferred form, an electrical actuator is provided at **130**, comprising typically a reversible electric motor linked via suitable reduction gearing to shaft coupling **129** and provided with suitable movement limiting devices. Such a typical control system is shown schematically in Fig. 10.

A reversible dual winding direct current motor is indicated at **132**, with mechanical connection to shaft **85** indicated at **133**. Energization of winding **134** of motor **132** drives shaft **85** in a direction to carry grid **50** from its operating position, indicated in solid lines, to its idle position, indicated in phantom lines at **50***a*. Energization of motor winding **135** drives shaft **85** in the opposite direction. Double throw limit switches are indicated at **136** and **137**, having their switch arms normally in upper position and being selectively actuated to lower position by shaft **85** when in active and idle positions, respectively. A source of electric power, shown illustratively as 28 volts direct current, is connected via a push button control switch **140** and the winding of a first relay **142** to ground; via the switch of relay **142** and the coil of a second relay **144**, which is a stepping relay having two steps, to ground; and to the switch arm of the stepping relay. The step contacts **145** and **146** of the stepping relay are connected to the respective arms of limit switches **136** and **137**. The normally closed contacts of those switches are connected to the motor windings **135** and **134**, respectively; and their normally open contacts are connected through signal lamps **147** and **148**, respectively, to ground.

Fig. 10 shows the apparatus in normal operating condition, with grid **50** in polarizing position. Signal lamp **147** is energized via stepping relay switch contact **145** and limit switch **136**, which is actuated by presence of shaft **85** in its operating position. The system is stable in that condition, since power circuits to motor coils **134** and **135** are open at relay contact **146** and at limit switch **136**, respectively. To shift the system to idle condition, with grid **50** in position **50***a* out of the radiation field, it is only necessary to press momentarily control switch **140**, which, with signal lamps **147** and **148**, may be remotely positioned from the rest of the apparatus. Relay **142** is thereby energized, actuating stepping relay **144** and shifting its switch arm from contact **145** to contact **146**. Signal lamp **147** is immediately turned out and power is supplied via limit switch **137** to motor winding **134**. The motor drives shaft **85** until the polarizing grid reaches idle position **50***a* and the shaft trip limit switch **137**. That cuts off power to the motor and lights signal lamp **148**, indicating idle position of the grid. A second momentary closure of control switch **140** returns the system to the condition shown in Fig. 10.

Limit switch **136** is preferably set to be tripped by shaft **85** when the latter has reached such a position as is shown in Fig. 6, with grid **50** held against stops **82** by relative compression of spring **122**, as already described. The operating position of the grid is thus determined by the position of stops **82**, which are accurately adjustable and of rugged construction, rather than by the setting of limit switch **136**, which therefore does not require precise adjustment.

The axial length of the antenna array and reflector may vary widely within the scope of the invention, being determined in practice by such factors as the degree of collimation that is required of the emitted radiation in the axial coordinate. Such variability is indicated schematically by the horizontal break in Fig. 3. Whatever the length of array **20**, grid **50** is correspondingly dimensioned to intercept substantially the whole of the primary beam. Whereas Fig. 3 shows explicitly only two array supports **60**, two shaft journals **90** and two grid support assemblies **100**, further such units may be provided as required.

It is typical of linear arrays of the type described that their emitted beam radiation, collimated in its axial coordinate as already stated, may not be directed exactly normal to the array axis, and may even form an appreciable, and perhaps a variable, oblique angle with respect to a plane normal to the array axis. Whereas that circumstance may affect the condition of polarization of the radiation in minor degree, it does not affect the fundamental principles of the invention nor appreciably alter the action of the antenna system as described.

We claim:

1. Antenna means for producing a beam of substantially circularly polarized radiation of a predetermined radio frequency, comprising a linear antenna array acting to project a primary radiation field that is linearly polarized and that is collimated in its axial dimension and divergent in its transverse dimension, a concave cylindrical reflector spaced from the array in the primary radiation field, the array axis lying substantially in the focus of the reflector, whereby the secondary radiation field reflected by the reflector is collimated in both said dimensions, and a grid between the array and the reflector, the grid being spaced relatively close to the array and relatively far from the reflector and intercepting substantially all of the primary radiation field and lying substantially outside of the secondary radiation field, said grid acting to transform the linearly polarized radiation of the primary field from plane polarized into substantially circularly polarized radiation, and the cylindrical reflector acting to alter the condition of collimation of that radiation while maintaining its condition of circular polarization.

2. Antenna means for producing selectively either linearly or circularly polarized beam radiation of a predetermined radio frequency, comprising a linear antenna array acting to project a primary radiation field that is linearly polarized parallel to the axis of the array and that is collimated in its axial dimension and divergent in its transverse dimension, a concave cylindrical parabolic reflector spaced from the array in the primary radiation field, the array axis lying substantially in the focus of the reflector, whereby the secondary radiation field reflected by the reflector is collimated in both said dimensions, and a grid selectively shiftable between an operating position in the primary radiation field and substantially outside of the secondary radiation field and an idle position substantially outside of both primary and secondary radiation fields, the grid acting when in its said operating position to transform the linearly polarized radiation of the primary field into circularly polarized radiation.

3. Antenna means as defined in claim 2 and in which the grid in idle position lies substantially in the axial plane of the reflector between the array and the reflector.

4. Antenna means as defined in claim 2 and in which the grid is mounted for selective pivotal movement about a pivot axis parallel to the array axis and spaced from the array toward the reflector substantially along the axial plane thereof.

5. Antenna means for producing selectively either linearly or circularly polarized beam radiation of a predetermined radio frequency, comprising a linear antenna array acting to project a primary radiation field that is

linearly polarized parallel to the axis of the array and that is collimated in its axial dimension and divergent in its transverse dimension, a concave cylindrical parabolic reflector spaced from the array in the primary radiation field, the array axis lying substantially in the focus of the reflector, whereby the secondary radiation field reflected by the reflector is collimated in both said dimensions, and a grid mounted for swinging movement about a pivot axis parallel to the array axis between an operating position in the primary radiation field and substantially outside of the secondary radiation field and an idle position substantially outside of both primary and secondary radiation fields, stop formations positively mounted with respect to the said array and cooperating

with the grid to define its said operating position, and yielding means for swinging the grid about the pivot axis into engagement with the stop formations, the grid acting when in its said operating position to transform the linearly polarized radiation of the primary field into circularly polarized radiation.

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