

June 3, 1969

R. S. ALFANDARI ETAL

3,448,455

ARMoured STRUCTURE ANTENNA

Filed March 22, 1965

Sheet 1 of 3

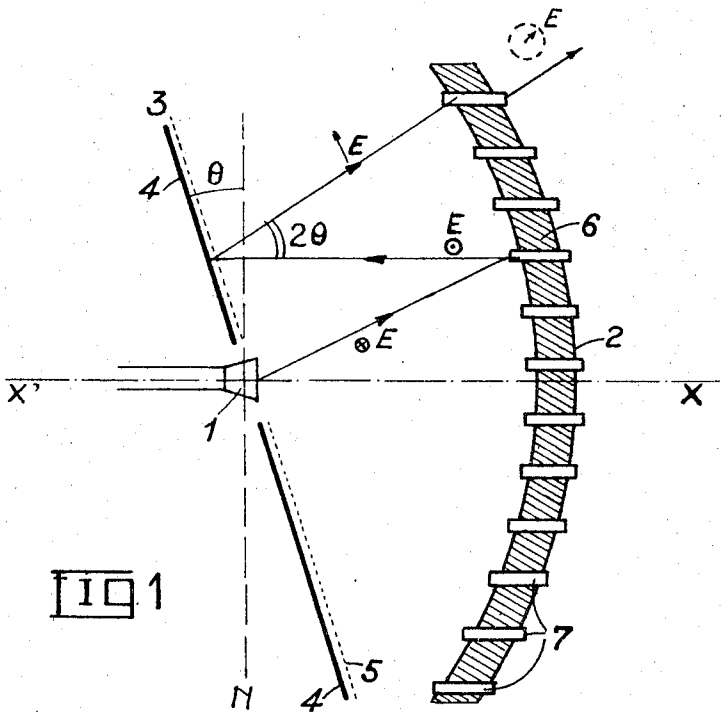


FIG. 1

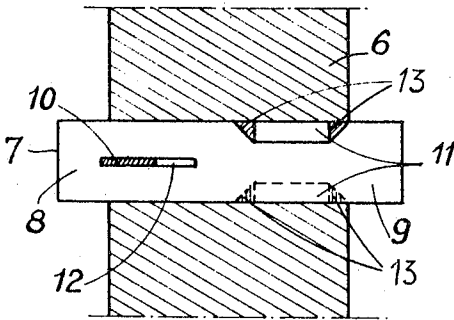


FIG. 3

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Sheet 2 of 3

FIG. 2

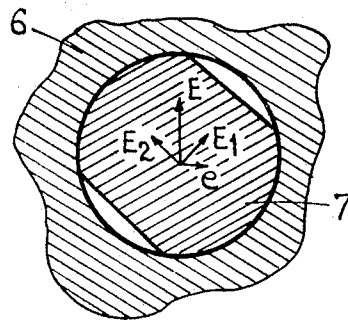
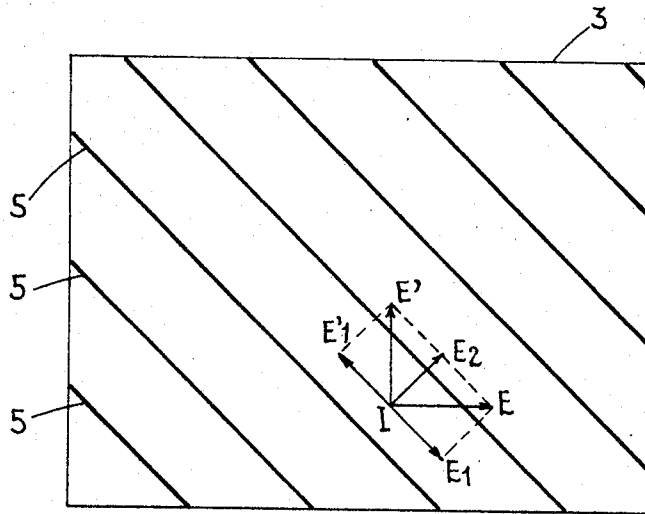


FIG. 4

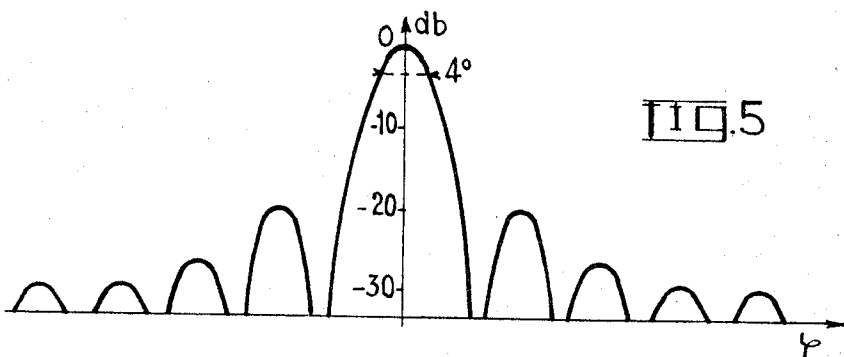


FIG. 5

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Sheet 3 of 3

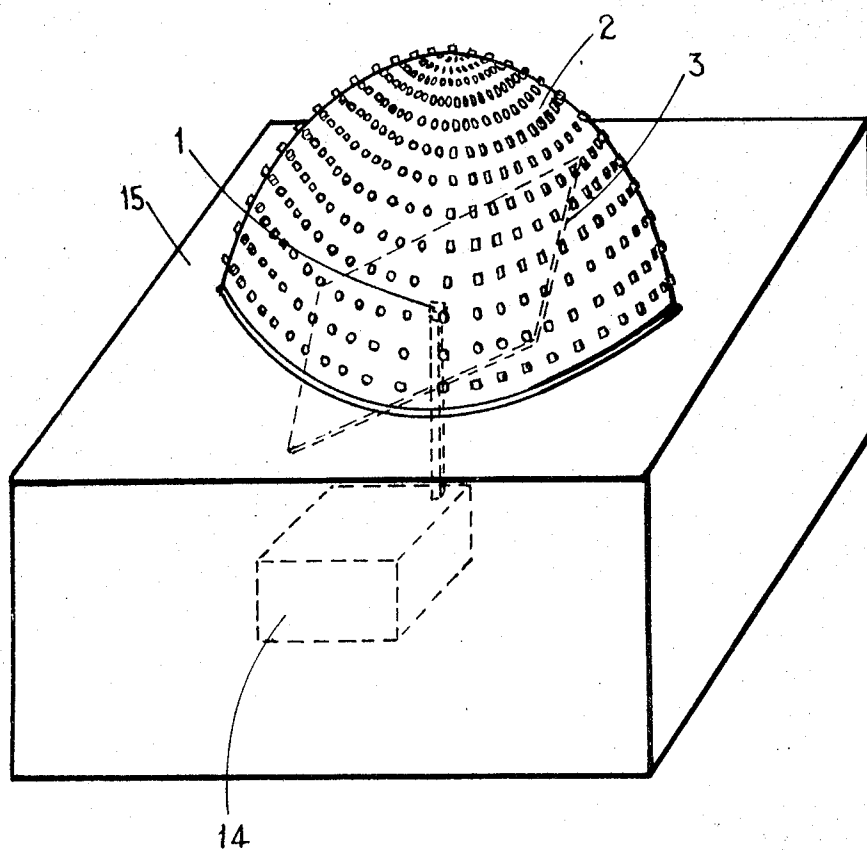


FIG. 6

1

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ARMOURED STRUCTURE ANTENNA
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ABSTRACT OF THE DISCLOSURE

An antenna assembly adapted to transmit and receive electromagnetic waves while withstanding severe operational conditions. A feed member provides the antenna with linearly polarized electromagnetic waves. A parabolic reflector is illuminated by these electromagnetic waves and, in turn, reflects them to a planar reflector. Upon reflection from the planar reflector member, a portion of the thus-reflected waves are transmitted by the parabolic reflector. The planar reflector is arranged to change the linear polarization of the waves while reflecting them back toward the parabolic reflector. The parabolic reflector is arranged to transmit the waves with the modified polarization so that the transmitted beam constitutes the radiated beam from the antenna assembly.

The present invention relates to an armoured structure antenna wherein the term "armoured" has the common military meaning sense involving broadly the concept of robustness, strength and resistance to severe external actions whatever they may be.

An antenna, in accordance with the present invention, relates particularly to UHF antennas of the so-called Cassegrain type although not exclusively limited to such kind of antennas.

This type of antenna comprises mainly a primary source radiating a UHF beam and two reflectors so arranged that the first reflector reflects the beam towards the second which in turn reflects it towards a target in the case of transmission. In the case of the reception, the reverse occurs. The first reflector is called auxiliary whereas the second is called main reflector. In the most simple and common Cassegrain structures, the primary feed is located in front of the auxiliary reflector, which is itself located in front of the main reflector. Generally, the emergizing beam from the main reflector is partially shadowed by the auxiliary reflector and it may also overlap the primary beam issuing from the source. This results in nontolerable deteriorations of the antenna radiation patterns, with the deteriorations increasing the level of the secondary or side lobes. To obviate these drawbacks, solutions have been contemplated, using polarized reflectors made of wire screen or parallel metallic blades with dielectric support, the latter being not necessary. The above reflectors reflect a linear polarized wave, the electrical field of which is parallel to the wires and are transparent to a linear polarized wave, the electrical field of which is perpendicular to the wires. Thus the component members of the antenna are so arranged that the auxiliary reflector reflects the wave issuing from the primary feed. Furthermore, the main reflector is such that, while reflecting the wave which illuminates it, a 90° rotation of its polarization plane is produced. Under these conditions, the auxiliary reflector is transparent to this reflected wave and the drawbacks related to the shadow area in those early structures are cancelled. But the antennas built in this

2

manner are nevertheless fragile and thereby difficult to use in practice when they must sustain severe handling, transportation, and operating conditions, and be sometimes also in heavily bombed areas.

An object of the present invention is to provide a UHF antenna which obviate the above shortcomings.

Another object of the invention is to provide also an antenna of the Cassegrain type, wherein the main reflector is movable.

Another object of the invention is to provide an armoured structure UHF antenna with a reflector member being a blindage.

Another object of the invention is to provide an antenna, wherein the auxiliary reflector may be extended so as to enclose the whole antenna assembly.

According to the invention, there is provided an UHF antenna assembly compact, tight and robust, which is transparent to electromagnetic waves of a given polarization plane and reflects waves the polarization plane of which is perpendicular to the latter. A polarized auxiliary reflector for a Cassegrain type aerial is thus built wherein the main reflector produces a 90° rotation of the polarization plane of the waves it reflects. The auxiliary reflector furthermore has means to convert the linear polarization of the transmitted waves into circular polarization and vice versa, and is made of a thick metallic member, bored so that the holes punched through said member constitute waveguides propagating a one mode wave, preferentially the fundamental mode. Each hole is furthermore filled with dielectric material incorporating rigid pieces protruding from the thick metallic plate and arranged to play as elementary antennas.

Other objects, features and advantages of the invention will become apparent from the ensuing description of an antenna with reference to the drawings wherein:

FIGURE 1 is a schematic view of the antenna assembly according to the invention;

FIGURE 2 is a vectorial pattern of the reflection process on the main reflector;

FIGURE 3 is a detail of the auxiliary reflector;

FIGURE 4 is a cut view of a quarter wave polarizer used in the invention;

FIGURE 5 is the radiation pattern of the antenna; and

FIGURE 6 is a schematic view of a totally armoured structure antenna according to the invention.

Referring to FIGURE 1, there is shown in longitudinal section an antenna assembly according to the invention. The antenna assembly comprises a primary feed 1, an auxiliary reflector 2 of a discontinuous structure and a main reflector 3. The XX' axis is a symmetry axis for the source 1 and the reflector 2; it is also a revolution axis for the antenna system. The primary feed 1 emits an electromagnetic wave of a given wavelength, linearly polarized for instance horizontally. In that case, the plane of FIGURE 1 is a vertical plane. As a first approximation, source 1 can be considered as a pinpoint source emitting a spherical wave. The geometric form of the reflector 2 is chosen according to the function it should perform. By way of example, reflector 2 is parabolic and the primary feed is located at its focus. The parabolic reflector 2 is so arranged that it reflects totally the horizontally polarized spherical wave emitted by the primary feed 1. After being reflected by reflector 2, this wave is converted into a plane wave, the equiphase planes of which are perpendicular to both the XX' axis and the plane of the FIGURE 1. This horizontally polarized plane wave reaches the main reflector 3 which is a flat plate owing to the desired emitted plane wave. Naturally, in the case where the reflector 2 or the association of reflector 2 and the source 1 which illuminates it, would have a different configuration than that shown, it should be better to give reflector 3 another shape so that the wave reflected by it

be a plane. But the chosen arrangement which is here described is advantageous when consideration is given to the scanning as will be later explained.

The reflector 3 consists of a metallic flat plate 4, perpendicular to the plane of the figure (in the chosen example) at an angle θ from the normal N to the axis XX'. The direction of the plane wave reflected by reflector 3 is then at an angle 2θ from the axis XX'. The reflector 3 further comprises a device rotating the polarization plane of the incoming wave by an angle of 90° . By way of example, this device may consist of a mesh of parallel metallic wires 5, at 45° with respect to the horizontal plane.

FIGURE 2 shows the angular rotation of the electrical field E after the wave has been reflected by reflector 3. The plane of this figure is that of the wires 5 of said reflector 3. The electrical field E of the incident ray incoming at I is horizontal and, thereby in the plane of the figure. If it is assumed that this ray is normal to the reflector plane 3, the obtained results remain valid as long as the angle of incidence θ , remains of a small value, what is always the case. The incident electrical field E may be broken down into two mutually perpendicular components of a same amplitude, say E1 parallel to the wires 5 and E2 perpendicular to the same. The distance between two neighboring wires is so chosen that the field component E2 passes the wire mesh while component E1 is reflected as E'1. Now, wires 5 are disposed at a distance from plane 4 equal to an odd number of quarter wave lengths. The result is that the transmitted field component E2 by the wires 5 is, after reflection on plane 4, delayed by 180° with respect to the directly reflected field component E'1. The resulting field E' from the reflector makes an angle of 90° with respect to the incident field E, that is to say the reflected wave from the reflector 3 is vertically polarized, the electrical field E' being in the vertical plane of FIGURE 1 perpendicular to the propagation direction. Reflector 2 has the property to transmit the vertically polarized waves. As a result the beam reflected from reflector 3 is transmitted practically unimpeded through reflector 2, and constitutes the radiated beam from the antenna.

A broader description of the reflector 2, according to the invention is given herebelow. It consists of a metallic plate 6 of a certain thickness which may be important in accordance with the conditions under which the whole antenna system is to be operated. The shape of this plate is chosen parabolic. This paraboloid 6 is pierced with holes, regularly spaced and all are identical and parallel throughout the plate 6. Dielectric elements 7 are located inside these holes. These are cylindrical to make the realization of the reflector easier. Each such cylindrical hole constitutes then a circular waveguide filled with dielectric. The characteristics of such a waveguide are so determined that at the utilization frequency, only the fundamental mode TE_{11} propagates therethrough.

All the component elements of reflector 2 are adapted for the system being totally transparent to a wave of a privileged polarization direction, in the present case, the vertical polarization. On the other hand reflector 2 totally reflects the wave the direction of polarization of which is orthogonal to the latter one. It must also be noted in connection with this reflector of a new type that the elements 7 all have the same length. For the wave reflected from reflector 3, the described antenna system behaves like an optical plate. The plane wave radiated from the antenna keeps on the same propagation direction, as the wave reflected by reflector 3 but, with respect to it, has sustained a transverse translation owing to the length of the elements 7.

FIGURE 3 shows a dielectric element such as disposed in a hole of the plate 6. This element consists of a cylindrical rod extending from the end 8 to the end 9, and comprises a thin metallic blade located 10, also called a short circuit blade nearer to the end 8 than to the end 9. The

blade is directed so as to reflect the wave emitted by source 1 and to transmit the wave reflected from reflector 3.

It follows from the foregoing that this blade is parallel to the polarization plane of the wave issuing from primary source 1, i.e. the blade is horizontal, in the chosen example. The wave emitted by source 1 is then totally reflected towards the main reflector 3. By observing the phenomenon from a macroscopic point of view, things are as if the wave were reflected by a totally metallic auxiliary reflector the surfaces of which were slightly displaced from the plate surface 4. The wave reflected from the main reflector is received by each elementary antenna formed by the ends 8 of the elements 7. These antennas of the dielectric type are so dimensioned that their radiation patterns, in the plane of the figure, for example, indicate a constant gain at the reception in the angular sector corresponding to the maximum angle of incidence of the incoming waves. The spurious reflections of the waves reflected by the main reflector 3 towards these antennas is thus reduced to a minimum. The wave received by each of these elementary antennas is then transmitted through the corresponding circular waveguides formed by the holes with metallic cylindrical wall, and filled with dielectric. In such a guide, the electrical field is, in the plane of FIGURE 1, perpendicular to the XX' horizontal axis, that is perpendicular to the plane of the short-circuit blade 10. This blade does not disturb the transmission of the wave through the corresponding elementary waveguide and the auxiliary reflector 2 is transparent to the wave reflected by the main reflector 3.

Finally, to produce a circularly polarized wave out of the antenna system, there is provided a quarter wave polarizer 11 at the outer end 9 of each dielectric element 7. This polarizer acts upon the two mutually perpendicular components of the electrical field, spaced at 45° with respect to the field, so as to delay one component by 90° over the other and to transform the rectilinear polarization into circular polarization. Such an action may be obtained by modifying the section of the elementary waveguide over a part of its length, bearing in mind that in an elliptical guide the phase velocities are different for two polarization directions parallel to the axes of the ellipse. The elliptical section of the waveguide will have for axis, straight lines at 45° with respect to the electrical field transmitted through element 7. In a simpler manner, the quarter wave polarizer may be obtained by cutting the dielectric cylinder along two parallel symmetrical planes with respect to the axis of said cylinder and tilted at an angle 45° to said axis.

FIGURE 4 shows a cross sectional view of the element 7 at level with the polarizer 11. The mutually perpendicular components E1 and E2 of the electrical field E are transmitted at different phase velocities by the portion of the guide, the section of which has been modified. The longitudinal dimension of the cut made in the section under consideration is so determined that, at the output of the polarizer, the components E1 and E2 are displaced 90° apart to each other and produce a circularly polarized field. Transition zones like 13 are provided to progressively pass from the circular section of each elementary guide to the desired section according to that shown in FIGURE 4, and thus reduce the spurious reflections due to the discontinuities in these guides. However, despite these precautions, it is possible that an incident wave, during its transmission through a waveguide element 7, sustains spurious reflections at the level with polarizer 11 and the ends of the element 7. These reflections let appear a spurious component of the electrical field perpendicular to the incident electrical field, that is, parallel to the blade 10. This component is then reflected by the blade 10 and produces, at level with the polarizer 11, a field e (see FIGURE 4) which is perpendicular to the field E of the incident wave or main field. It follows that, at the output of the polarizer 11, this field e is circularly polarized but

in reverse sense with respect to the main field E and the resulting field of the beam radiated by the antenna system is elliptically polarized. To obviate this short-coming, there is provided, at the rear of blade 10, opposite to the end 8, a portion of material 12, in the form for instance, a blade with absorbent material which is parallel to blade 10. This extra blade absorbs the spurious electrical fields perpendicular to the main field.

Such portions of blades are often called "cross polarization absorbers." They allow the system to provide for the utmost accurate possible circular polarization to the emitted wave.

The radiated beam from the antenna system is in fact a combination of the elementary beams radiated each by the end 9 of each dielectric element 7 playing as an elementary antenna. All these elementary antennas, which are distributed over the auxiliary reflector constitute an array which, in a first approximation, may be considered as a planar array. In order to prevent grating lobes in the pattern of this array, the spacing between two elements 7 is chosen equal to the half wavelength of the used wavelength.

By way of example, FIGURE 5 shows the radiation pattern of an antenna system according to the invention, operating in the 3 cm. band, wherein the auxiliary reflector 2 consists of a steel plate of a thickness which can be greater than 3 cm., pierced with holes 7 mm. diameter. The holes are about 16 mm. spaced apart, and the diameter of the antenna is about 50 cm. Reference angle φ represents the angle between the radiating direction and the horizontal line XX' . The width at 3 db of the main lobe is about 4° . It must be noted that the illuminating law of the array made of the dielectric elements 7, allows to be reduced, the level of the side lobes, the first side lobes being in the described example 20 db below the main beam. As a matter of fact, since the primary feed 1 is not omnidirectional, the illumination of the main reflector is not uniform—being more outstanding at the center of the reflector than at the edge thereof. Consequently the radiation pattern of the array is improved with respect to that of a uniformly illuminated array.

In the foregoing it has been noted that the plane reflector 3, was at an angle θ from the normal N to the axis XX' , the radiating direction of the reflected ray b . The reflector 3, then make an angle 2θ with said XX' axis. Indeed, in several practical applications, the reflector 3 may be moved as to produce a scanning of the beam. Said reflector 3 may, for instance, rotate about the line N , the θ angle being then varied between two extreme values on either side of point O .

The emitted beam is then scanned in the plane of FIGURE 1 on either side of axis XX' . The scanning of the beam may also be made around the XX' axis, in the horizontal plane, perpendicular to the plane of the FIGURE 1. To achieve that, the reflector 2 is rotated about its trace on the plane of FIGURE 1. The combination of these two motions allows a scanning of the beam downwards and from left to right. This scanning is made easier by the simple shape itself of the reflector 3 and further it does not lead to any deformation or deterioration of the emitted wave since the rotation of the reflector 3 does lead but to an alteration of the direction of the reflected plane wave with respect to the incident wave. The obtained deviation angles may be somewhat important.

It is now obvious to those skilled in the art that the above described antenna operates in the same way as well at the reception as at the transmission, although the different components of said antenna appear to have only been described in connection with the transmission.

It can also be noted that the above described antenna system behaves like a high pass filter, since each elementary waveguide punched through the auxiliary reflector 2 does not transmit waves of a guided wavelength less than the cutoff frequency corresponding to the geometrical

dimensions of said guide. This consideration is advantageous to protect a receiving antenna against a nearby transmission at a higher wavelength.

Another outstanding advantage of the antenna system, disclosed hereinabove is that the auxiliary reflector 2 is made of a steel plate or other appropriate metal, has a thickness, which may be of a relatively high value, though not limited, and may withstand considerable forces whatever their origin. Furthermore, the dielectric material filling the hole provided in the plate may also have a great strength so that the whole reflector assembly does not shown any weak point which could reduce its resistance capability. Such a dielectric material may be, inter alia, alumina which presents a relatively high dielectric constant leading to relatively small hole diameter.

The auxiliary reflector itself is capable of withstanding considerable impacts, being in that respect similar to an armour plate. Furthermore, the armoured reflector is sealed tight to water, gas, steam, etc. Under these conditions, the above reflector may be used as a blindage for the whole antenna assembly, playing as a real reflector the proper functions it is fit for. These functions are described in what precedes. It can also function as a protective radome, totally enclosing said whole antenna assembly.

Such a sheltering structure is shown in FIGURE 6, which represents a Cassegrain antenna of the type above described, totally enclosed in its own auxiliary reflector as under a rigid metallic radome. This deflector 2 formed by a portion of a paraboloid encloses the primary feed 1 and the main reflector 3. The transmit-receive device 14 associated with the antenna is located inside an isolated enclosure 15 upon which rests the reflector 2.

Such an assembly can be provided to protect apparatus and operators against some severe dangers like, for instance, those coming from nuclear radiations. In that case, the enclosure 15 may be a shelter of concrete and the reflector 2, is made of lead of sufficient thickness so as to prevent the nuclear radiations to pass through it, thereby protecting all that is inside the assembly.

It is furthermore, always possible to provide a device like the reflector 2, which is transparent to the electromagnetic energy and acts only as a radome under which any type of antenna could be located. For that purpose, it would only be necessary to suppress the short-circuit blades 11 from the dielectric rods 7.

It will be understood that a large number of modifications may be introduced into the exemplary embodiments described and shown herein without departing from the scope of the invention.

What we claim is:

1. An antenna assembly of the Cassegrain type, comprising, in combination, a primary feed illuminating a first polarized reflecting member with linearly polarized waves, said waves being reflected by said first reflecting member in the direction of second reflecting means, said first polarized reflecting member consisting of a paraboloid of thick metallic plate adapted to electrical functions, said first polarized reflecting member being adapted to withstand severe operational conditions, said second means consisting of a flat metallic plate tilted at an angle to the axis of the system, said axis being the focal line of said paraboloid and said primary feed being located at the focus of said paraboloid, said metallic flat plate being provided with a wire screen located slightly in front of said flat metallic plate for changing the polarization of the waves reflected by said first polarized member in the direction of said flat plate, said means with said metallic flat plate rotating the electrical field of said waves by 90° while reflecting them in the direction of said first polarized reflecting member, said first polarized reflecting member including holes punched through said metallic reflecting member to constitute waveguides filled with dielectric and adapted to transmit electromagnetic waves of a given mode, said waves at the output of each waveguide combining to form the radiated beam from said antenna assembly.

2. The antenna assembly as defined in claim 1, including dielectric rods of a dense and rigid material adapted to the shape of said holes, said rods protruding from said first member and being arranged to act as elementary antennas whereby the waves transmitted through said first member are radiated by said elementary antennas to form the radiated beam from said antenna assembly.

3. The antenna assembly as defined in claim 2, wherein said dielectric rods in the thick metallic reflecting member are all parallel and of the same length, said dielectric rods functioning as an optical flat for the transmitted waves passing therethrough.

4. The antenna assembly as defined in claim 2, wherein two adjacent dielectric rods are spaced apart by half a wavelength.

5. The antenna assembly as defined in claim 1, wherein said holes punched through said first reflecting member are cylindrical and constitute waveguides of circular cross section.

6. An antenna assembly of the Cassegrain type comprising, in combination, a primary feed illuminating a first polarized reflecting member with linearly polarized waves, said waves being reflected by said first reflecting member in the direction of second reflecting means, said first polarized reflecting member consisting of a paraboloid of a suitable material adapted to electrical functions, said member being adapted to withstand severe operational conditions, said second means consisting of a flat metallic plate tilted at an angle to the axis of the system, said axis being the focal line of said paraboloid and said primary feed being located at the focus of said paraboloid, said metallic flat plate being provided with means changing the polarization of the waves reflected by said first polarized member in the direction of said flat plate, said means with said metallic flat plate rotating the electrical field of said waves by 90° while reflecting them in the direction of said first polarized reflecting member, said first polarized reflecting member including cylindrically punched holes each having a dielectric rod protruding from said first reflecting member and functioning as an elementary antenna for the waves reflected from said flat metallic plate, said rods comprising each a quarter wave polarizer whereby a linearly polarized wave in a given plane coupled to these elementary antennas is converted to a circularly polarized wave and vice versa, said wave forming the radiated beam from the antenna assembly.

7. An antenna assembly for transmitting and receiving electromagnetic waves under severe environmental and operating conditions comprising, in combination, a source of polarized electromagnetic waves; first armored means in the path of said electromagnetic waves emanating from said source and being illuminated by said electromagnetic waves, said first armored means having a reflecting surface for reflecting the electromagnetic waves directed onto said surface by said source; said reflecting means in the path of the electromagnetic waves reflected by said reflecting surface of said first armored means, the electromagnetic waves from said first armored means impinging upon said second reflecting means; polarization changing means on said second reflecting means for changing the polarization of the electromagnetic waves reflected by

said first armored means and directed onto said second reflecting means, the electromagnetic waves with changed polarization being reflected by said second reflecting means and directed onto said first armored means; and wave guide means having dielectric rods in said first armored means for transmitting through said first armored means the electromagnetic waves with changed polarization after being reflected by said second reflecting means, whereby the electromagnetic waves which change polarization combine after transmission through said wave guide to form a beam of electromagnetic waves radiating from said antenna.

8. The antenna assembly for transmitting and receiving electromagnetic waves under severe environmental and operating conditions as defined in claim 7 wherein said electromagnetic waves from said source are linearly polarized, said environmental and operating conditions including shock and vibration.

9. The antenna assembly for transmitting and receiving electromagnetic waves under severe environmental and operating conditions as defined in claim 8 wherein said polarization changing means rotate by 90° the electrical field of said linearly polarized waves from said source of polarized electromagnetic waves, said wave guide means including means for transmitting only electromagnetic waves polarized by said polarization changing means, so that the electromagnetic waves radiated in a beam from said antenna have their electric field rotated 90° from that in the linearly polarized electromagnetic waves from said source.

10. The antenna assembly for transmitting and receiving electromagnetic waves under severe environmental and operating conditions as defined in claim 9 wherein said first armored means comprises a polarized reflector reflecting waves of a predetermined polarization while transmitting waves of another different polarization.

11. The antenna assembly for transmitting and receiving electromagnetic waves under severe environmental and operating conditions as defined in claim 9 wherein said first armored means comprises a paraboloid and said second reflecting means comprises a flat metallic plate tilted at an angle to a line coincident with the focal line of said paraboloid, said source of polarized electromagnetic waves being located at the focus of said paraboloid.

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ELI LIEBERMAN, *Primary Examiner*.

U.S. Cl. X.R.

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