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DOUBLE-REFLECTOR ANTENNA WITH POLARIZATION-CHANGING SUBREFLECTOR

Filed March 9, 1961

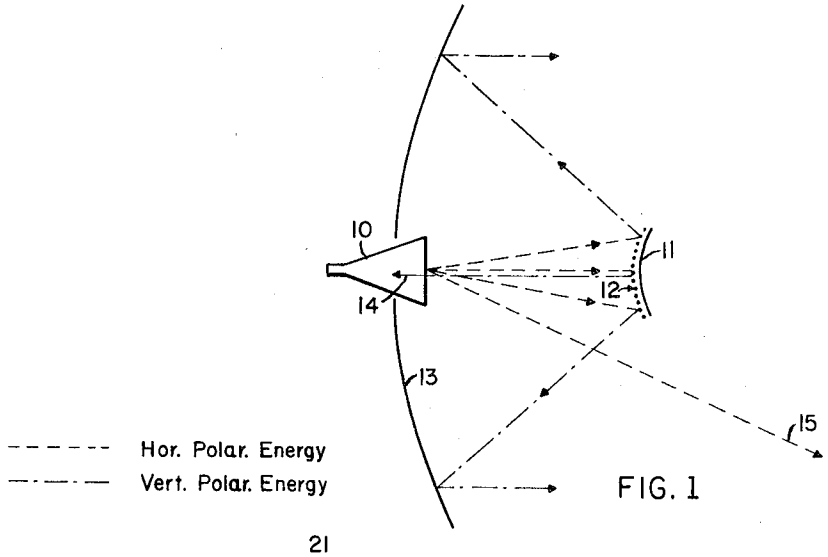
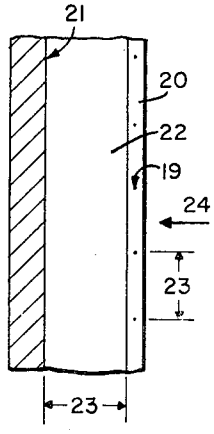
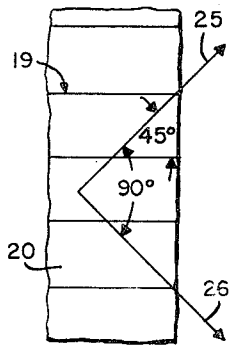


FIG. 1



(a)



(b)

FIG. 2

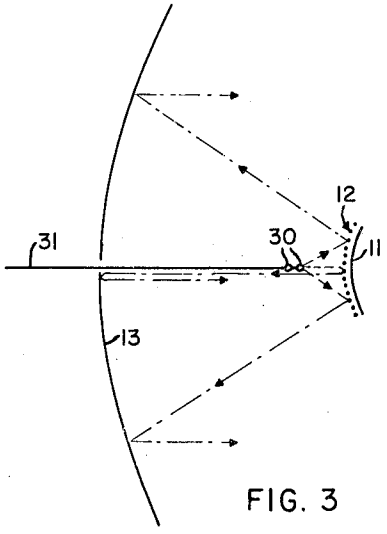


FIG. 3

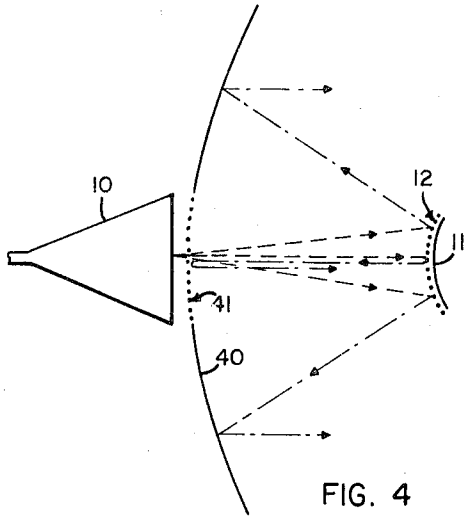


FIG. 4

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3,235,870

DOUBLE-REFLECTOR ANTENNA WITH POLARIZATION-CHANGING SUBREFLECTOR

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This invention relates to antennas having a feed cooperating with a subreflector which, in turn, cooperates with a main reflector, and more particularly to such antennas wherein the subreflector changes the polarization of an electromagnetic wave which it reflects.

In the design of an optical telescope, the Cassegrain double-reflector system has often been utilized. Compared with the single-reflector type, it achieves a high magnification with a short focal length, and allows a convenient rear location for the observer. Recently, a number of microwave antennas have been developed which employ double-reflector systems similar to that of the Cassegrain telescope.

A Cassegrain telescope consists of two mirrors and an observing optical instrument. The primary mirror, which is a large concave mirror in the rear, collects the incoming light and reflects it toward the secondary mirror, which is a small convex mirror out in front. The secondary mirror then reflects the light back through a hole in the center of the primary mirror. When the incoming rays of light are parallel to the telescope axis, the final bundle of light rays is focused toward a point; at this location the observer places his eye or his camera.

In the basic microwave antenna derived from the Cassegrain telescope, the microwave reflectors, which will be called the main reflector and the subreflector, have surfaces similar in shape to those of the telescope. The microwave feed is a small antenna which, together with a transmitter or receiver, replaces the optical instrument of the telescope.

Analysis of the operation of a Cassegrain antenna system may be performed with the same semi-optical approximation commonly employed with an ordinary single-reflector antenna. Usually the feed is sufficiently small so that the wave radiated by the feed can be described by the far-field pattern of the feed before reaching the subreflector, and the wave incident on the subreflector appears to travel along the rays originating from a point centered on the feed. The subreflector, which must be large enough to intercept the useful portion of the feed radiation, ordinarily reflects this wave essentially according to ray optics. On reaching the main reflector, the wave is again reflected according to ray optics, and, because of the geometry of the antenna elements, the rays emerge parallel and the wave front has the flat shape which is usually desired. The amplitude of the emergent wave across the aperture has a taper which is determined by the radiation pattern of the feed, modified by the additional tapering effect of the antenna geometry. The far-field pattern of the antenna is a diffraction pattern whose characteristics depend on the amplitude taper of the emergent wave.

The geometry of the Cassegrain system is simple and well known. The classical Cassegrain geometry employs a parabolic contour for the main reflector and a hyperbolic contour for the subreflector. One of the two foci of the hyperbola is the real focal point of the system, and is located at the center of the feed; the other is a virtual focal point which is located at the focus of the parabola. As a result, all parts of a wave originating at the real focal point, and then reflected from both surfaces, travel equal distances to a plane in front of the antenna. The invention is also applicable to variations of

the classical Cassegrain system, including variations which resemble classical Gregorian telescope. It is also applicable to other double-reflector systems having reflecting surfaces with contours quite different from those of the Cassegrain or Gregorian telescopes.

There are several problems involved in the design of double-reflector microwave antennas. One problem is impedance mismatching of the feed caused by reflection of the transmitted wave back into the feed by the subreflector. Another concerns the radiation of a spurious wave by virtue of direct radiation from the feed. A third problem is blocking of the main aperture by the feed and subreflector.

It is an object of this invention, therefore, to provide double-reflector antennas which avoid one or more disadvantages of the prior art.

It is an additional object of this invention to provide double-reflector antennas with reduced undesirable reflections from the subreflector into the feed.

It is a further object of this invention to provide double-reflector antennas in which harmful effects resulting from direct radiation by the feed are avoided.

It is a further object of this invention to provide double-reflector antennas with reduced aperture blocking.

It is a further object of this invention to provide efficient double-reflector microwave antennas.

In accordance with the invention, a double-reflector antenna capable of receiving and transmitting signals of vertical polarization comprises a horn dimensioned to support waves of horizontal polarization only; polarization changing subreflector means for changing a horizontally polarized wave radiated by the horn to a vertically polarized wave and for reflecting the vertically polarized wave back toward the horn. The antenna also comprises a main reflector for redirecting the reflected wave back past the subreflector means, the antenna being so constructed and arranged that the horn is unaffected by the wave reflected by the subreflector means as a result of the change in polarization.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

In the drawing:

FIG. 1 is a side view of a double-reflector antenna in accordance with the invention;

FIG. 2 includes two views of polarization-changing means utilized in the FIG. 1 antenna;

FIG. 3 illustrates another double-reflector antenna in accordance with the invention which utilizes a dipole-type feed, and

FIG. 4 illustrates an additional double-reflector antenna in accordance with the invention which utilizes a polarization-sensitive grating in the main reflector.

Referring now to FIG. 1 of the drawing, there is shown a double-reflector Cassegrain-type antenna having a feed in the form of horn **10**, cooperating with subreflector means shown as including a simple metallic subreflector **11** and associated polarization-changing means **12**, which, in turn, cooperates with a main reflector **13**.

In operation, this antenna is capable of receiving and transmitting waves of a predetermined polarization, in this example shown to be a vertically polarized wave. Feed **10** has a polarization different from the polarization of the complete antenna; in this example the feed is designed for operation with horizontally polarized waves. Feed **10** acts as a primary antenna for effecting the transition between a free-space electromagnetic wave and a guided electromagnetic wave and vice versa. Considering operation during transmission, the feed **10** radiates a

horizontally polarized electromagnetic wave which is directed towards the subreflector means **11** and **12**. The polarization-changing means **12** coupled to the reflecting surface of subreflector **11** changes the polarization of the wave reflected by the subreflector, and in this example the reflected wave becomes vertically polarized. This wave, after reflection from said subreflector means **11** and **12** is, in turn, reflected by the main reflector **13** in the well-known manner to form a desired beam or pattern. All this is illustrated in FIG. 1 by the various dotted rays. As indicated by the legend of FIG. 1, a horizontally polarized wave is indicated as a simple dotted ray path and a vertically polarized wave by an alternate dash-dot ray path.

It will now be appreciated that since the feed **10** and its associated waveguide is designed for a horizontally polarzed wave, that portion of the wave (as represented by ray path **14**) that is directed back into feed **10** after reflection by the subreflector means **11** and **12** will be vertically polarized and will be rejected by the feed. As a result, the reflection by the subreflector means will not disturb the impedance characteristics of the feed.

Also, it will be appreciated that any part of the wave (as represented by ray path **15**) radiated by the feed **10** which bypasses the subreflector means **11** and **12** is essentially horizontally polarized (in this example), while the desired wave radiated by the complete antenna is vertically polarized. In many applications in accordance with the invention, only that radiation which exists in the desired polarization will couple to the object with which the antenna is communicating, and in these cases the spurious radiation past the subreflector will have substantially no harmful effect.

It should further be appreciated that in many practical antennas, the feed **10** may radiate sidelobes of greater strength in the plane of its polarization than in the orthogonal plane. In prior art antennas designed to operate with vertical polarization, these sidelobes would tend to bypass the subreflector means **11** and **12**, and those below the subreflector (as represented by ray path **15**) could couple to the ground and create harmful effects. With the present invention, the feed can be oriented so that its plane of polarization is horizontal and only the weaker sidelobes couple to the ground. Thus the harmful effects caused by interaction of the ground with the spurious radiation past the subreflector may be minimized.

Referring now to FIG. 2, there is illustrated an example of polarization-changing means which may be utilized in accordance with the invention.

As shown in FIG. 2*a*, the polarization-changing means **12** may be in the form of a screen made up of a series of parallel metal wires, such as **19**, supported by a thin fiberglass skin **20**. Skin **20** is supported and spaced from the metal surface **21** of the subreflector by a relatively low dielectric constant honeycomb material **22**, whose thickness is such that the wires are effectively separated from the metal surface by approximately ⅜ of the effective operating wave length. The term "effective operating wave length" refers to the actual wave length of a single frequency system or the average or midband wave length over an operating frequency band width, divided by the average cosine of the angles of incidence of the wave and the subreflector surface. The wire diameter and spacing **23** are such that the normalized inductive susceptance equals approximately 2. A wave incident in direction **24** and having a linear polarization, as indicated by arrow **25** in FIG. 2*b*, will be reflected with a polarization as shown by arrow **26**. Similar polarization-changing means used in a different manner are described in more detail in applicant's application, Serial No. 80,961, filed January 5, 1961, and entitled "Twistreflector," now Patent No. 3,161,879, and are also mentioned in applicant's application, Serial No. 92,504, filed March 1, 1961, and entitled "Double-Reflector Antenna With Minimum Aperture Blocking."

Referring now to FIGS. 3 and 4, there are shown arrangements whereby aperture blocking is reduced. In these antennas, polarization techniques are employed to render the feed invisible to those waves which would ordinarily be blocked by the feed.

In FIG. 3 the feed **30** is composed of thin horizontal elements fed by a transmission line **31**, and is positioned between the subreflector means **11** and **12** and the main reflector **13**. This type of feed will be termed a "dipole-type feed." This feed may be greatly enlarged including many more members than are shown. When the feed **10** radiates a horizontally polarized wave toward subreflector means **11** and **12**, the vertically polarized wave returned by the subreflector means passes through the feed substantially unaffected by the feed and is completely reflected by the main reflector **13**, after which the wave again passes through the feed.

In the FIG. 4 arrangement, a horizontally polarized feed **10** is located behind the main reflector **40**. The main reflector **40**, which is positioned between the feed **10** and the subreflector means **11** and **12**, includes a central portion in the form of a vertical grating **41**. This grating is made up of thin parallel conductive wires closely spaced compared with a wave length and has the properties of being essentially a perfect reflector for a wave of polarization parallel to the wires and essentially invisible to a wave of perpendicular polarization. This grating may be supported in a fiberglass skin or by other methods. In the FIG. 4 arrangement the feed **10** radiates a horizontally polarized wave through the central grating **41** toward the subreflector means **11** and **12** which reflect the wave and change its polarization to vertical. This vertically polarized wave is then completely reflected by the main reflector **40** including grating **41**.

In the configurations of both FIG. 3 and FIG. 4 it is evident that the subreflector means cause aperture blocking but the feed does not. Consequently, the feed may be greatly enlarged so that its increased directivity allows the subreflector to become quite small. As a design consideration, when the feed becomes equal to or larger than the subreflector, the phase front across the feed aperture should be curved so as to focus the feed toward the vicinity of the main reflector focus. It should also be mentioned that when this condition exists, the historic geometry of the Cassegrain system no longer applies exactly. However, the basic operation of the antenna remains similar.

Another application for the technique of FIG. 3 and FIG. 4 involves a feed system having many independent radiators to achieve a particular requirement. One example is an antenna which must radiate a cluster of many adjacent beams; another example is a shaped-beam antenna. When the compound feed system is large, it is desirable to eliminate the large amount of aperture blocking which it would ordinarily cause.

In an antenna actually constructed in accordance with the invention, the polarization-changing means had the following dimensions. The dimensions refer to FIG. 2 and all dimensions are normalized to wave length.

Wire **19** diameter	0.046λ
Wire spacing **23**	0.18λ
Honeycomb **22** thickness	0.29λ to 0.35λ
Skin **20** thickness	0.016λ

It will now be appreciated that antennas constructed in accordance with this invention avoid impedance mismatching of the feed due to radiated waves reflected back into the feed from a subreflector. Other benefits may be realized if spurious waves, created by direct radiation by the feed past the subreflector, are capable of causing harmful effects. Finally, the invention allows reduced aperture blocking by the feed and subreflector.

While the discussion of antennas in accordance with this invention has been directed mainly toward the transmission or radiation of waves by the antenna, the invention is equally effective during reception of waves by the antenna, by virtue of the reciprocity principle. It should also be appreciated that although the invention has been described for the case of a vertically polarized antenna with a horizontally polarized feed, it is also applicable to a horizontally polarized antenna and a vertically polarized feed, or other combinations of polarization.

While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention and it is, therefore, aimed to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A Cassegrain-type antenna capable of receiving and transmitting a wave of a predetermined polarization comprising: a feed having a polarization different from said predetermined polarization; subreflector means cooperating with said feed for reflecting and changing the polarization of an incident wave; and a main reflector positioned between said feed and subreflector means and having a grating which reflects waves of said predetermined polarization and passes waves of said different polarization.

2. A double-reflector antenna capable of receiving and transmitting a wave of a predetermined polarization comprising: a feed having a polarization different from said predetermined polarization; a subreflector cooperating with said feed; polarization-changing means coupled to said subreflector for producing a change in the polarization of a wave reflected by said subreflector; and a main reflector positioned between said feed and subreflector and having a grating which reflects waves of said predetermined polarization and passes waves of said different polarization.

3. A double-reflector antenna capable of receiving and transmitting a wave of a predetermined polarization comprising: a feed having a polarization differing by 90° from said predetermined polarization; a subreflector cooperating with said feed; polarization-changing means coupled to said subreflector for producing a 90° polarization change in the polarization of a wave reflected by said subreflector; and a main reflector positioned between said feed and said subreflector and having a grating which reflects waves of said predetermined polarization and passes waves having a polarization differing from said predetermined polarization by 90°.

4. A double-reflector antenna capable of receiving and transmitting signals of vertical polarization comprising: a horn dimensioned to support waves of horizontal polarization only; polarization changing subreflector means for changing a horizontally polarized wave radiated by said horn to a vertically polarized wave and for reflecting the vertically polarized wave back toward said horn; and a main reflector for redirecting said reflected wave back past said subreflector means; the antenna being so constructed and arranged that the horn is unaffected by the wave reflected by the subreflector means as a result of the change in polarization.

5. A double-reflector antenna in accordance with claim 4, wherein the aperture of said horn lies between the main reflector and the subreflector means.

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