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3,231,892

ANTENNA FEED SYSTEM SIMULTANEOUSLY OPERABLE AT TWO
FREQUENCIES UTILIZING POLARIZATION INDEPENDENT
FREQUENCY SELECTIVE INTERMEDIATE REFLECTOR

Filed June 26, 1962

3 Sheets-Sheet 1

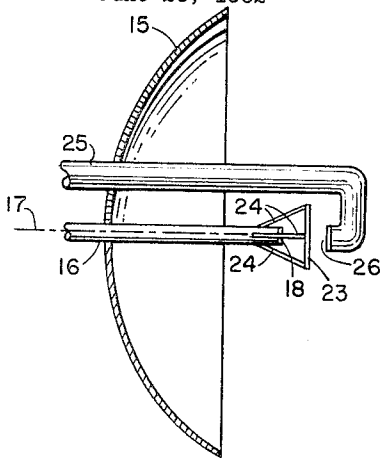


FIG. 1

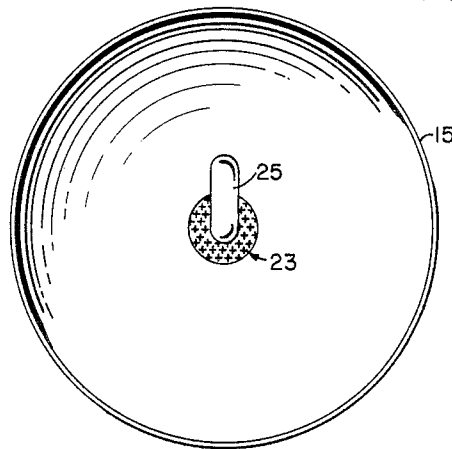


FIG. 2

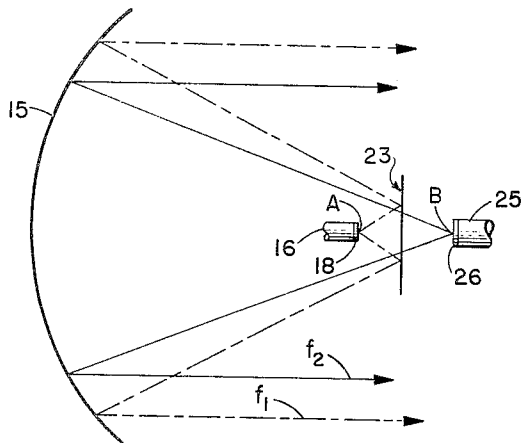


FIG. 3

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3 Sheets-Sheet 2

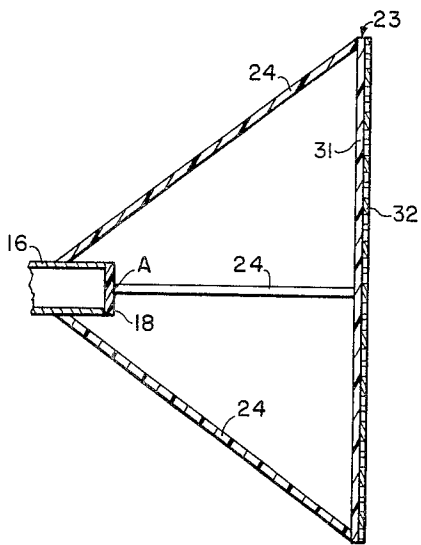


FIG. 4

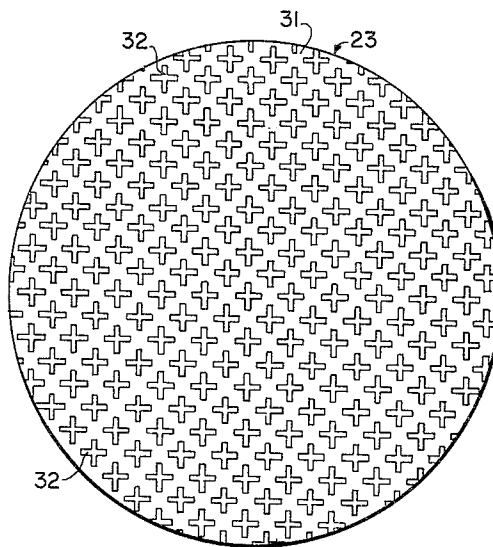


FIG. 5

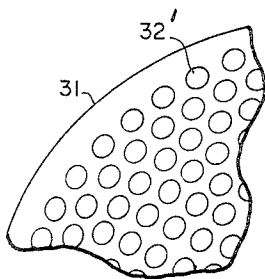


FIG. 6

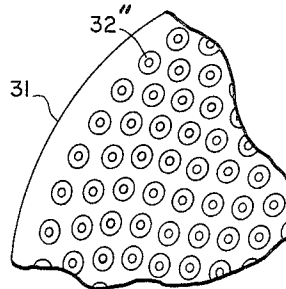


FIG. 7

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3 Sheets-Sheet 3

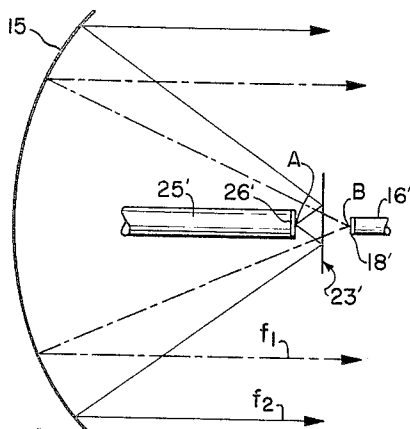


FIG. 8

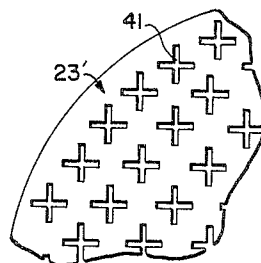


FIG. 9

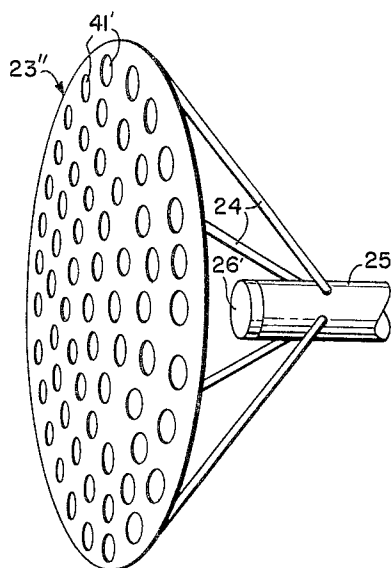


FIG. 10

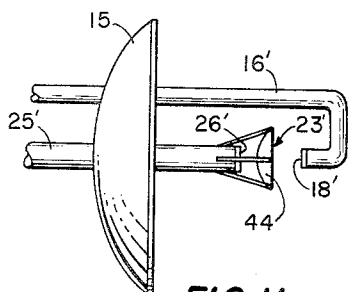


FIG. 11

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ANTENNA FEED SYSTEM SIMULTANEOUSLY OPERABLE AT TWO FREQUENCIES UTILIZING POLARIZATION INDEPENDENT FREQUENCY SELECTIVE INTERMEDIATE REFLECTOR

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19 Claims. (Cl. 343-775)

This invention relates to an antenna feed system and more particularly to an antenna feed system which is simultaneously operable at two frequencies.

In recent years there has been a trend toward the operation of antenna systems of the parabolic reflector type at more than one frequency, and this trend has resulted in the development of multi-frequency, multi-purpose feed systems for use with a single parabolic reflector. One such prior art system comprises a horn feed located at the focus of a parabolic reflector and two dipoles positioned on either side of the horn, the horn providing a primary source and the dipoles providing a secondary source of radiation for the reflector. It is apparent that both the horn feed and the dipoles cannot be located at the focus of the reflector, and therefore the radiation patterns of the dipoles are distorted. In other prior art antenna feed systems adapted for radiation of energy from two sources, a feed horn is located at the focus of the parabolic reflector and a splash plate is positioned adjacent thereto and may be energized for example from a position below the reflector. The splash plate feed is defocused, resulting in a large loss in gain with a corresponding deterioration in the radiation pattern and side-lobe level.

A prior art antenna feed system which overcomes the defocusing difficulty of the above mentioned arrangements uses a Cassegrainian feed employing a secondary reflector comprising a wire grating. Feed horns for providing energy in two different frequency bands are located at opposite sides of the secondary reflector of the Cassegrainian feed system and are directed thereat. One horn is located at the focal point of the parabolic antenna reflector while the second horn and the Cassegrainian reflector are positioned so that the virtual focal point of the second feed horn is located at the focus of the parabola. With this arrangement the center of feed of both feed horns appears to be at the focus of the reflector. In operation, the energy from one feed source must be polarized parallel to the wires of the grating while that from the other feed source is orthogonal thereto. A major limitation of such an arrangement is that both feed systems are limited to a single linear polarization.

An object of this invention is the provision of an antenna system for operation at two frequency bands simultaneously, which system overcomes the limitations of the prior art arrangements.

An object of this invention is the provision of an antenna arrangement which includes a pair of feed systems simultaneously operable at two different frequencies and adapted for the illumination of a single paraboloidal reflector, which feed systems have no polarization limitations.

An object of this invention is the provision of a Cassegrainian feed system which includes a secondary reflector which is an efficient reflector of energy at one band of frequencies and is substantially completely transparent at all frequencies removed from the said one band of frequencies, which system is polarization insensitive.

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An object of this invention is the provision of means modifying existing parabolic antenna systems operable at a given frequency for simultaneous operation at a second frequency without necessitating a major modification in the existing antenna system and without a deterioration in the radiation pattern and sidelobe levels.

These and other objects and advantages of the invention are accomplished by means of a Cassegrainian-type feed system employing a secondary reflector comprising a plurality of adjacent resonant elements. The geometry of a Cassegrainian-type system is well known and includes a parabolic main reflector and a Cassegrainian secondary reflector which, in a true Cassegrainian system is hyperbolic in shape but in practice may be flat. A feed source, such as a circular horn, radiates energy in the direction of the Cassegrainian reflector which energy is reflected in the direction of the parabolic reflector where the energy is again reflected. A virtual image of the feed source is located at the focus of the parabola, whereby the said feed source appears to be located at such focus point. The Cassegrainian-type system described above is modified by the inclusion of a second feed source located at the actual focus of the parabolic reflector, from which second source energy at a different frequency than that from the first feed source is directed toward the parabolic reflector through the Cassegrainian reflector which is transparent to energy from the second feed source. Unlike prior art arrangements, the Cassegrainian reflector is transparent to energy of any polarization from the second feed source, and reflects energy of any polarization from the first feed source. In accordance with this invention the Cassegrainian reflector comprises a plurality of resonant elements of any geometric two-dimensional shape having symmetry about a point, which elements are, therefore, capable of being energized by waves of any polarization. In one embodiment of the invention the resonant elements comprise conductors resonant at the frequency of the energy from the first feed source, while in a second embodiment of the invention the resonant elements comprise apertures formed in a conducting plate, which apertures are resonant at the frequency of the energy from the second feed source.

In the drawings wherein like reference characters refer to the same parts in the several views:

FIGURE 1 is a side elevational view of an antenna system embodying this invention, parts being shown broken away for clarity;

FIGURE 2 is a front elevational view of the antenna system shown in FIGURE 1;

FIGURE 3 is a schematic diagram of the antenna system of FIGURE 1, showing the path of the energy from the feed sources;

FIGURE 4 is an enlarged vertical cross-sectional view of the Cassegrainian reflector employed in the system shown in FIGURE 1;

FIGURE 5 is an enlarged front view of the Cassegrainian reflector;

FIGURE 6 is a fragmentary front view of a modified Cassegrainian reflector which may be employed in the antenna system shown in FIGURE 1;

FIGURE 7 is similar to FIGURE 6 only showing another modified form of Cassegrainian reflector;

FIGURE 8 is a schematic diagram similar to FIGURE 3 but showing another feed system embodying this invention;

FIGURE 9 is a fragmentary front view of the Cassegrainian reflector used in the antenna system shown in FIGURE 8;

FIGURE 10 is a perspective view of a modified form of Cassegrainian reflector suitable for use in the arrangement shown in FIGURE 8; and

FIGURE 11 is a side elevational view of an antenna system similar to that shown in FIGURE 8 but showing a Cassegrainian reflector having a hyperbolic surface of revolution rather than a flat surface.

Reference is now made to FIGURES 1 and 2 of the drawings wherein there is shown an antenna system which incorporates in one structure the separate functions of two antennae which are simultaneously operable. The arrangement comprises a modified Cassegrainian-type system having a reflector 15 which is in the form of a surface of revolution. In the conventional Cassegrainian arrangement the reflector 15 is in the form of a paraboloid of revolution. However, it will be apparent that the reflector may assume other shapes as desired. A first feed system for the reflector 15 includes a circular wave guide 16 adapted for connection to a suitable source, or utilization circuit, of high frequency energy. The wave guide 16 extends along and is coincident with the axis of revolution 17 of the paraboloidal reflector 15 and terminates in a circular horn, or feed member 18. A Cassegrainian reflector 23 is mounted and spaced from the feed 18 by means of low-loss dielectric supports 24 extending between the wave guide 16 and reflector 23. Although a flat reflector 23 is shown in FIGURES 1 and 2, it will be understood that the invention is not limited thereto. In the true Cassegrainian geometry the Cassegrainian reflector comprises a hyperbolic surface of revolution. However, numerous variations in the form of both the main reflector 15 and Cassegrainian reflector 23 are possible within the scope of this invention, which forms obey the basic formulae describing a Cassegrainian system.

Reference is now also made to FIGURE 3 of the drawings wherein the center of the feed 18 is designated point "A," and point "B" designates the focus of the paraboloidal reflector 15. For purposes of explanation, the combination of the feed 18 and Cassegrainian reflector 23 may be considered as replaced by a virtual feed at the focal point "B" of the reflector 15. Thus, energy waves, designated f_1 , from the feed 18 may be considered as originating at the focus "B" of the paraboloidal reflector 15 so that the system, described thus far, functions as an ordinary single reflector arrangement.

The Cassegrainian system described thus far is modified by the inclusion of a second feed system comprising a cylindrical wave guide 25 which is shown extending from the rear of the paraboloidal reflector 15 and terminating in a circular horn, or feed member 26 in front of and spaced from the Cassegrainian reflector 23. The center of feed of the horn 26 is located on the axis 17 at the focus "B" of the paraboloid 15. The Cassegrainian reflector 23 is transparent to energy from the feed 26, whereby the paraboloidal reflector 15 is illuminated by the energy from the feed 26 passing through the Cassegrainian reflector, the energy waves from feed 26 being designated f_2 in FIGURE 3 of the drawings. Suitable means, not shown, such as dielectric ropes may be secured to the wave guide 25 and extend to suitable supports, not shown, for maintaining the center of the feed 26 at the point "B" under all orientations of the antenna system and environmental conditions encountered thereby.

Unlike prior art dual antenna systems, the Cassegrainian reflector 23 provides an efficient reflector for energy of any polarization from the feed 18 and is also substantially completely transparent to energy of any polarization from the feed 26. In the embodiment of the invention shown in FIGURES 1-3 the novel Cassegrainian reflector comprises, as seen in FIGURE 4, a low loss dielectric board 31 which may comprise a glass fiber member impregnated with a plastic such as Teflon. On the face of the board there are a plurality of closely spaced resonant members, designated 32, which may be printed on or otherwise suitably secured thereto. The

resonant members may be of any geometric two dimensional shape having symmetry about a point. As best shown in FIGURE 5 of the drawing, the resonant members 32 may be in the form of crosses, alternate arms of which form pairs of perpendicular passive dipoles. The dipoles are made resonant at the frequency of the energy radiated from the feed 18 and are placed sufficiently close together to provide an effective reflector at this frequency without interfering with the passage of energy through the reflector from the feed 26. In the illustrated arrangement the energy from the feed 18 is preferably at a higher frequency than that from the feed 26. The feed system which includes the feed 18 may operate at 2250 mc., for example, while the feed system which includes the feed 26 may operate at 400 mc. The resonant elements 32 are made resonant at the high frequency and are placed close enough together to provide a mutual impedance therebetween having a first order effect. In this manner the radiation resistance of the elements is made very small for maximum reflection of the high frequency energy from feed 18.

The bandwidth of the novel Cassegrainian reflector depends directly on the bandwidth of the reflecting resonant elements, or crossed dipoles 32. The bandwidth of the dipoles may be controlled by the width of the resonant elements printed on the board 31, the width referring to the dimension across the arms as viewed in FIGURE 5. If, for example, it is only necessary to operate over a narrow high frequency band, the dipoles may be made very thin, and as a result the scattering of the low frequency energy will be very small. As an example of one practical arrangement which includes an 85-foot diameter paraboloidal reflector 15, the crosses 32 may be printed on a board 31 which is 0.062 inch thick and 54 inches in diameter. Approximately 300 resonant elements 32 having arms approximately 2.5 inches long and 0.375 inch wide may be included on the board for operation at the above mentioned frequency of 2250 mc. For a parabolic reflector 15 in which the ratio of the focal length to diameter is equal to 0.42 the high frequency horn 18 may have an aperture of 4.25 square inches spaced 12 inches from the frequency selective reflector 23. With other paraboloidal reflectors having a lower focal length to diameter ratio, the horn aperture may be reduced in size and spaced closer to the reflector.

The invention is not limited to the particular shape of the resonant elements 32 employed in the Cassegrainian reflector. As shown in FIGURE 6 of the drawings the elements may comprise, for example, circles designated 32'. The circles are a wave length in circumference at the high frequency and are staggered in a manner similar to the crosses. As shown in FIGURE 7 of the drawings, the resonant elements may comprise annular members designated 32''. Such members may have a circumference equal to one wave length of the high frequency energy. It will be apparent that other forms of resonant members may be employed in the Cassegrainian reflector provided they are symmetrical about a center point for operation with energy of any polarization.

A second form of an antenna system embodying this invention is shown in FIGURE 8 of the drawings to which reference is now made. In FIGURE 8 a high frequency energy feed system is shown comprising a circular wave guide 16' and feed 18' positioned in front of the Cassegrainian reflector 23' for illumination of the paraboloidal reflector 15, through the Cassegrainian reflector. A low frequency energy feed system comprising a cylindrical wave guide 25' and feed 26' is positioned behind the Cassegrainian reflector 23'. Energy from the feed 26' is directed to the Cassegrainian reflector 23' from which it is first reflected. The energy reflected from the Cassegrainian reflector is directed to the paraboloidal reflector 15, from which it is again reflected, the paths of high and low frequency energy waves being shown schematically by the broken and solid lines designated

f_1 and f_2 , respectively. The Cassegrainian reflector 23' comprises a conducting, non-magnetic metal sheet in which a plurality of resonant apertures are formed. As seen in FIGURE 9, the apertures, designated 41, may be of cruciform shape similar to the dipole arrangement of FIGURE 4. In accordance with Babinet's theory, the reflector 23' becomes transparent over one frequency band only, and in accordance with this invention the slots are made resonant at the frequency of the energy from feed 18' and are, therefore, transparent to the high frequency energy therefrom. The low frequency energy from the feed 26' is reflected by the metallic sheet 23' back to the reflector 15. The center of the feed 18' is located at the focus "B" of the paraboloidal reflector 15, while the feed 26', having a center at point "A," provides a virtual feed for the low frequency energy at point "B." The dipole slots 41 pass energy of any polarization from feed 18'.

It will be apparent that the system is not limited to the use of cruciform slots 41. In the perspective view shown in FIGURE 10, there is shown a reflector designated 23'' in which a plurality of circular holes 41' are formed which circular holes are resonant at the frequency of the energy from the high frequency source 18'.

As mentioned above the Cassegrainian reflector employed in the antenna system of this invention is not limited to the flat shape shown. In the true Cassegrainian geometry, the Cassegrainian reflector is in the form of a hyperbolic surface of revolution. In FIGURE 11 there is shown a system which is similar to that shown in FIGURE 8 but uses a hyperbolic reflector 44 rather than a flat one. A wide variety of forms may be employed for both the Cassegrainian reflector and the reflector 15.

The invention now having been described in detail in accordance with the requirements of the patent statutes, various other changes and modifications will suggest themselves to those skilled in this art. For example, although a transmitting antenna system has been shown and described, it will be apparent that the arrangement will function equally well as a receiving antenna system. It is intended that such changes and modifications shall fall within the spirit and scope of the invention as recited in the following claims.

We claim:

1. An antenna system for simultaneously radiating energy at two different frequencies, comprising a paraboloidal reflector having a first focus, a frequency responsive reflector positioned in front of said paraboloidal reflector with the axes of said reflectors in substantial coincidence, said paraboloidal reflector and said frequency responsive reflector in combination having a second focus, a first feed adapted to supply microwave energy of a first frequency, said first feed being positioned at said second focus and directing energy at the frequency responsive reflector from which said energy is reflected to the paraboloidal reflector, a second feed adapted to supply microwave energy of a second frequency, said second feed being positioned at said first focus and directing energy at the paraboloidal reflector through the frequency responsive reflector, said frequency responsive reflector being transparent to energy of any polarization from said second feed and reflecting energy of any polarization from the said first feed.

2. The invention as recited in claim 1 wherein said frequency responsive reflector comprises a plurality of spaced metallic elements having shapes possessing two-dimensional symmetry about a point and being resonant at said first frequency, said second frequency being lower than the said first frequency.

3. The invention as recited in claim 1 wherein said frequency responsive reflector comprises a plate of conducting metal, means forming in said plate a plurality of apertures having a shape possessing two-dimensional symmetry about a point and being resonant at said sec-

ond frequency, said second frequency being higher than said first frequency.

4. An antenna system operable simultaneously at two different frequencies, comprising

- (1) first means reflective of electromagnetic waves of both said frequencies, said means having a first focus,
- (2) second means transmissive of electromagnetic waves of one of said frequencies and any polarization and reflective of electromagnetic waves of the other of said frequencies and any polarization, said second means being so positioned with respect to said first means and having such a configuration that, at said other frequency, said first means and said second means in combination have a second focus displaced from said first focus,
- (3) a first feed, operative at said one frequency, positioned at said first focus, and
- (4) a second feed, operative at said other frequency, positioned at said second focus.

5. An antenna system according to claim 4, wherein said second means comprise a plurality of spaced conductive elements resonant at said other frequency.

6. An antenna system according to claim 4, wherein said one frequency is lower than said other frequency and said second means comprise an array, in a dielectric medium, of spaced conductive elements resonant at said other frequency.

7. An antenna system according to claim 4, wherein said one frequency is lower than said other frequency and said second means comprise an array, in a dielectric medium, of spaced conductive elements, each resonant at said other frequency and each having two-dimensional symmetry about a point.

8. An antenna system according to claim 7, wherein each of said elements is cruciform.

9. An antenna system according to claim 7, wherein each of said elements is annular.

10. An antenna system according to claim 7, wherein each of said elements is discoidal.

11. An antenna system according to claim 4, wherein said second means comprise a conductive sheet having a plurality of spaced apertures resonant at said one frequency.

12. An antenna system according to claim 4, wherein said one frequency is higher than said other frequency and said second means comprise a conductive sheet having an array of spaced apertures resonant at said one frequency.

13. An antenna system according to claim 4, wherein said one frequency is higher than said other frequency and said second means comprise a conductive sheet having an array of spaced apertures, each resonant at said one frequency and each having two-dimensional symmetry about a point.

14. An antenna system according to claim 13, wherein each of said apertures is cruciform.

15. An antenna system according to claim 13, wherein each of said apertures is circular.

16. An antenna system according to claim 4, wherein said second means are constructed to transmit waves of said one frequency without substantially changing their direction of travel.

17. An antenna system according to claim 4, wherein said first means comprise a paraboloidal reflector.

18. An antenna system according to claim 17, wherein said second means have a plane configuration and both said first means and said second means are perpendicular to the same axis.

19. An antenna system according to claim 17, wherein said second means have a convex hyperboloidal configuration and both said first means and said second means are perpendicular to the same axis.

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