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DUAL FREQUENCY GREGORIAN-NEWTONIAN ANTENNA SYSTEM WITH NEWTONIAN FEED LOCATED AT COMMON FOCUS OF PARABOLIC MAIN DISH AND ELLIPSOIDAL SUB-DISH

Filed May 13, 1964 3 Sheets-Sheet 1

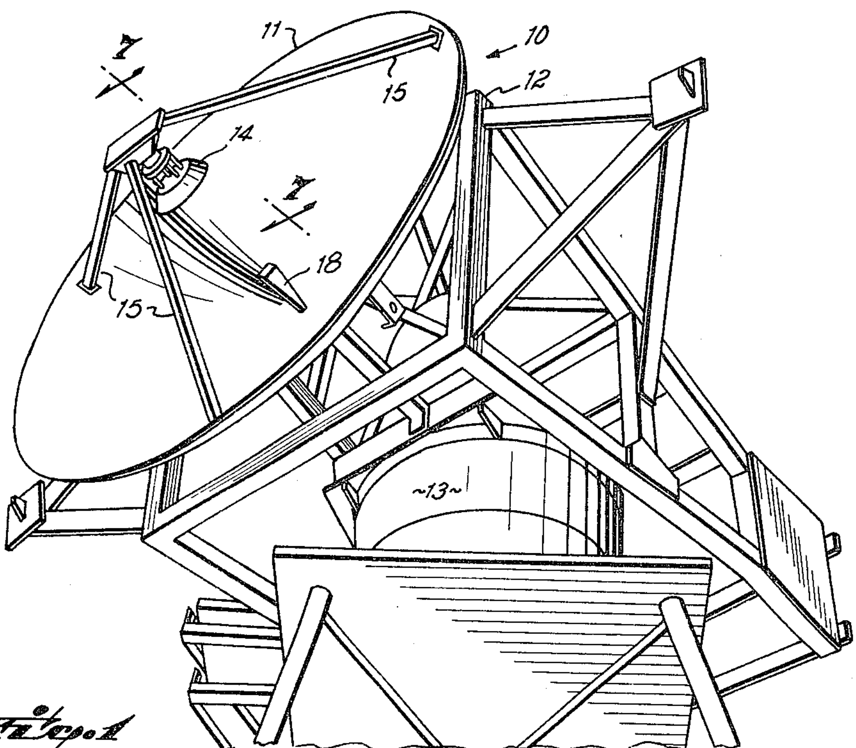

Fig. 1

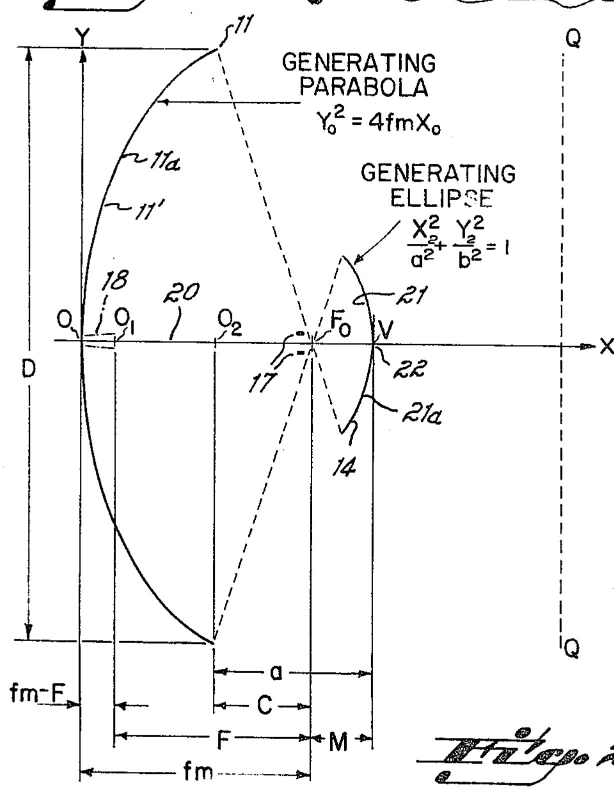

Fig. 2

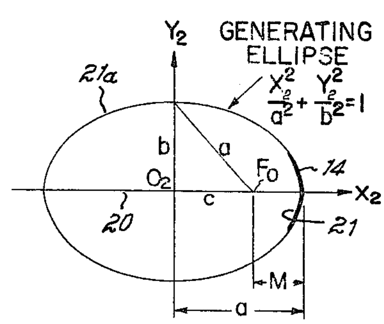

Fig. 3

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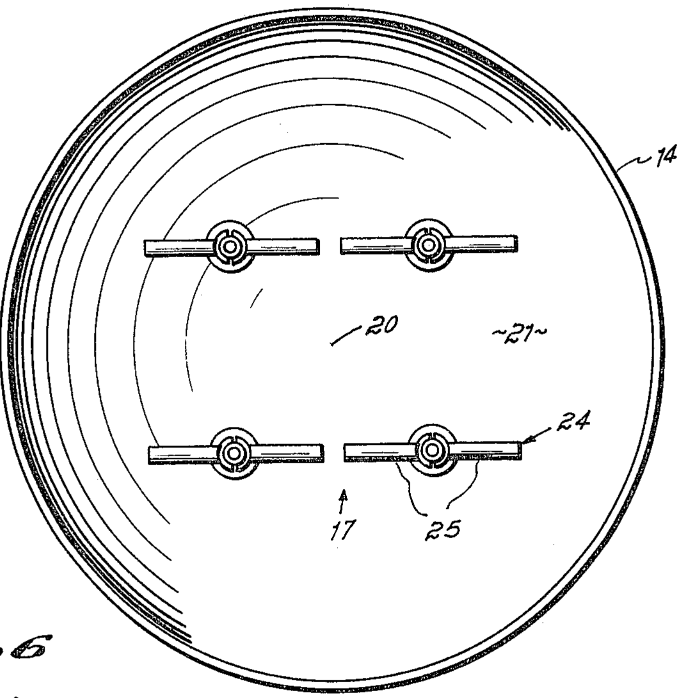

FIG. 6

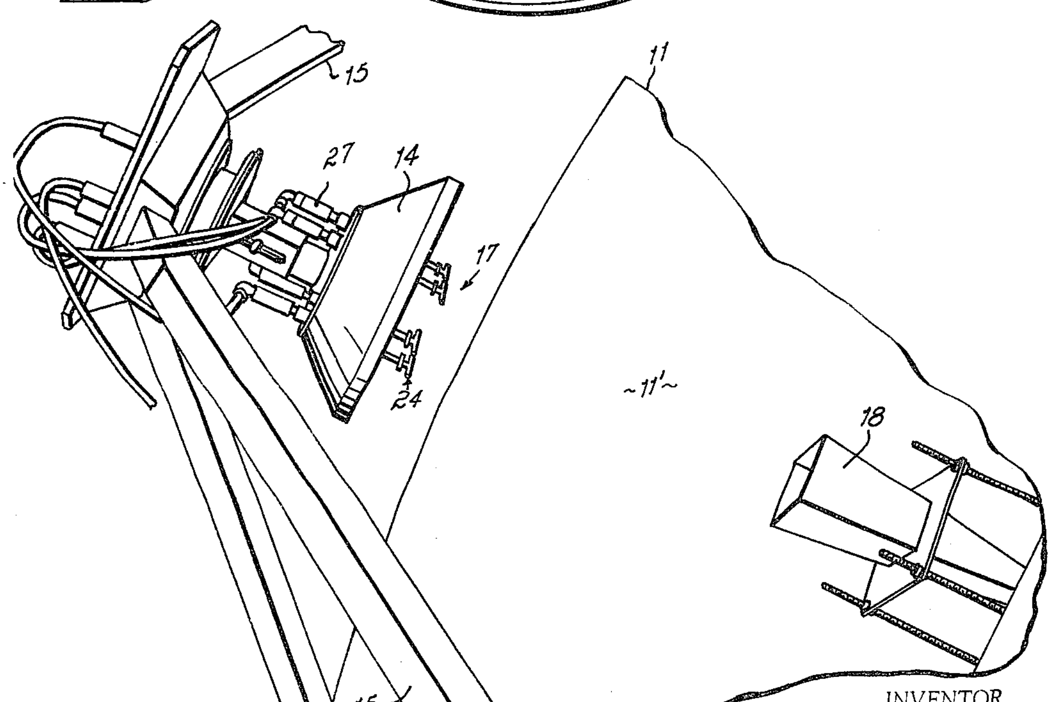

FIG. 7

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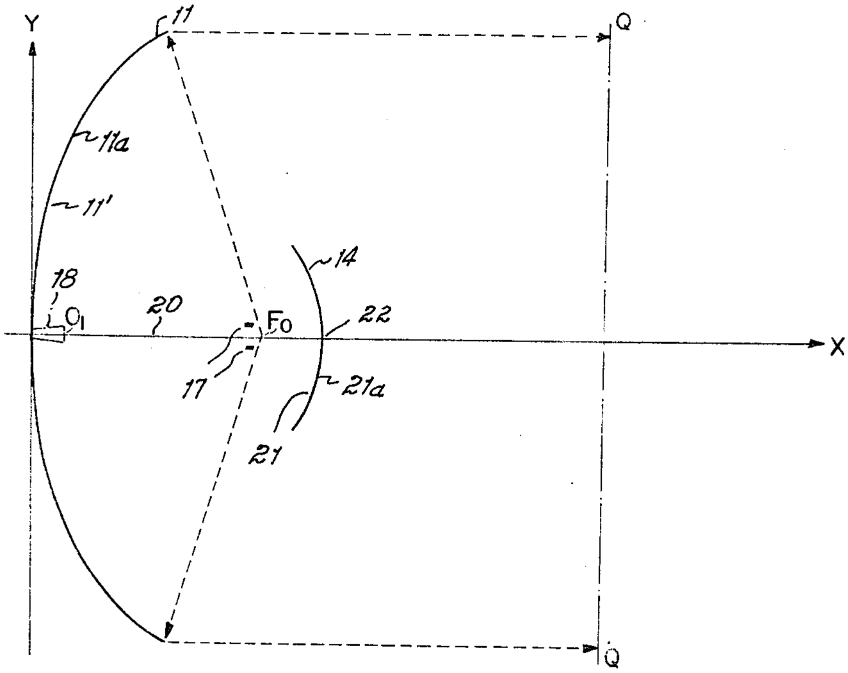

Fig. 4

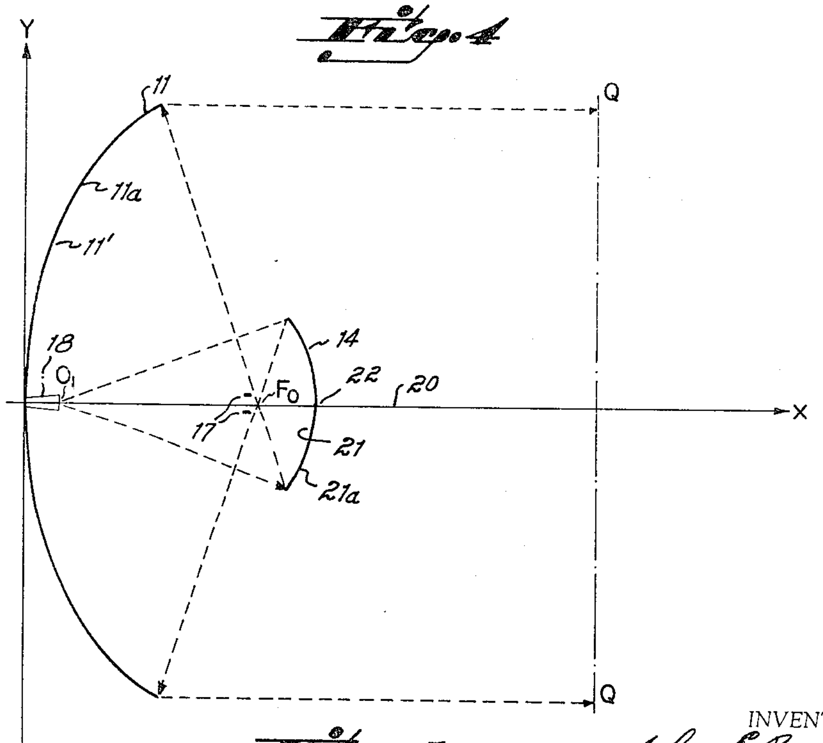

Fig. 5

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6 Claims. (Cl. 343—727)

This invention relates to antenna constructions and is particularly directed to a novel antenna system effective to operate simultaneously or sequentially at two widely different frequencies, for example, at one frequency in the VHF range and another in the UHF or SHF range.

At the present time it is desirable that antennas for use in fields, such as missile and satellite tracking and telemetering work, operate at any of a number of different frequencies, the higher frequencies being of an order of more than thirty times the frequencies at the lower end of the range. More particularly, prior to 1960 nearly all manned aircraft, missile and satellite telemetry and communications were conducted on a band in the VHF range, i.e., in the 220–260 mc. band. This band is also still used for telemetry from boosters in missile launches. At the same time, however, much higher frequencies are utilized in connection with telemetry from newer missiles and satellites. For example, telemetry and command signals are transmitted in the UHF range from 1500 to 2400 mc., and SHF frequencies from 7200 to 10,000 mc.

The principal object of the present invention is to provide a single antenna which can be operated at any frequency in the VHF, UHF and SHF bands, and which can in fact be operated simultaneously at two widely divergent frequencies, for example 220 mc. in the VHF band and 8000 mc. in the SHF band.

More particularly, the present invention is predicated upon the concept of providing an antenna system comprising the combination of a single main paraboloidal reflector provided with a Newtonian feed at the focus of the paraboloid and an ellipsoidal sub-reflector effective to cooperate with the main reflector and with a second feed at a focus of the ellipse to provide a Gregorian antenna unit.

The present antenna system comprises a paraboloidal main reflector and an ellipsoidal sub-reflector disposed so that one focus of the ellipsoidal sub-reflector coincides with the focus of the paraboloid. The ellipsoidal reflector is disposed on the side of said common focus remote from the paraboloidal main reflector. A suitable Newtonian VHF feed, for example a dipole array, is disposed adjacent the common focus. This feed functions in combination with the paraboloidal reflector to provide the Newtonian unit of the antenna system. In this Newtonian unit the ellipsoidal sub-reflector serves as a ground plane. The system also includes a second UHF or SHF feed, for example a feed horn, located at the second focus of the ellipsoid. The combination of this second feed horn, the ellipsoidal reflector and paraboloidal reflector function as the Gregorian unit of the antenna system.

The present invention is predicated in part upon the empirical discovery and determination that the elements of the two systems are compatible, i.e. the elements necessary for one system do not adversely affect the operation of the other system to an objectionable degree. Specifically, it has been found that the operation of the Gregorian portion of the antenna system is only minimally affected by the presence of the dipole array in front of the ellipsoidal reflector. Similarly, the adverse affects on the operation of the Newtonian portion of the system due to the use of an ellipsoidal ground plane rather than the ideal planar ground plane are well within tolerable limits.

One important advantage of the present antenna system is that it can be operated simultaneously at two widely divergent frequencies. Moreover, the present antenna can be operated sequentially at widely different frequencies without any need for physically modifying the antenna to change from one frequency to another.

Another important advantage of the present antenna system ish that it provides two different types of antennas, each type being effective to provide optimum efficiency for signals in a particular frequency range. Specifically, in the VHF frequency range the ray-optical performance of a double reflector system, such as a Gregorian system, deteriorates rapidly because the physical size of the sub-reflector is no longer large with respect to the wave length. Also, gain loss and side lobe degradation render the use of an antenna system of this type impractical in this frequency range. In accordance with the present invention, the double reflector system is not utilized in this range, but rather a Newtonian feed is provided with the result that optimum antenna performance is achieved in the VHF range.

At the same time, in the UHF and SHF range, the Gregorian double reflector system is utilized. The system provides many advantages leading to optimum performance in these ranges including low spill over, reduced space attenuation and convenient location of the primary feed adjacent to the paraboloid vertex.

Another very important advantage of the present antenna system is that it utilizes a single main paraboloidal reflector surface. This is particularly important since it facilitates the construction of a large antenna, for example an antenna 60′ in diameter, a size which would not be practical if it were necessary to provide two main paraboloidal reflectors.

Still another advantage of the present invention is that both the main paraboloidal reflector and the ellipsoidal sub-reflector are provided with conventional reflector surfaces, i.e. neither of these surfaces is required to be selectively reflective of one radiation frequency and/or polarization and transmittive of the other.

A further advantage of the present invention is that the axis of both the Newtonian antenna unit and the Gregorian antenna unit are coincident, with both feeds lying substantially on the common axis. This simplifies positioning of the antenna and handling of the antenna signals.

These and other objects and advantages of the present invention will be more readily apparent from a consideration of the following detailed description of the drawings illustrating a preferred embodiment of the invention.

In the drawings:

FIGURE 1 is a perspective view of one antenna system constructed in accordance with the present invention.

FIGURE 2 is a diagrammatic view showing the geometric relationship of the components of the system.

FIGURE 3 is a diagrammatic view showing the parameters of the ellipsoidal reflector.

FIGURE 4 is a diagrammatic view showing the ray geometry of the Newtonian feed portion of the antenna system.

FIGURE 5 is a diagrammatic view showing the ray geometry of the Gregorian portion of the antenna system.

FIGURE 6 is a front elevational view of the ellipsoidal reflector and the dipole array for providing the Newtonian feed.

FIGURE 7 is an enlarged view taken generally along line 7—7 of FIGURE 1.

One preferred form of antenna system **10** constructed in accordance with the principles of the present invention comprises a paraboloidal main reflector **11** carried by a frame structure **12**. The frame **12** is in turn connected to a drive unit **13** which is effective to shift the antenna both in azimuth and elevation. It is to be understood that the frame and antenna drive are conventional and constitute no part of the present invention. In fact, the present antenna can be mounted upon a stationary support, if desired, in a particular installation.

In addition to the main paraboloidal reflector member **11**, the present antenna system comprises a secondary ellipsoidal reflector member **14** mounted in front of main reflector **11**, as by means of support beams **15**. The antenna system further comprises a Newtonian feed, such as dipole array **17**, carried by the ellipsoidal reflector member **14** and located at the focus of the paraboloidal reflector. A second, or Gregorian, feed member such as horn **18** extends through an opening in the vertex of the parabola and is directed toward the ellipsoidal reflector.

The exact geometry and manner of functioning of the antenna system components is shown diagrammatically in FIGURES 2–4. More particularly, the front face **11'** of reflector **11** is a continuous reflective paraboloid surface formed of a conductive metal, such as aluminum. This surface is generated by rotating a generating parabola **11*a*** about axis **20**. As is shown in FIGURE 2, the generating parabola **11*a*** has a focal point F_o which also corresponds to the focal point of the paraboloidal reflector surface **11'**. The focal length of the parabola is designated *fm* and the locus of the generating parabola in the Cartesian system shown in FIGURE 2 with the origin O is $Y_0^2=4fmX_0$. The paraboloidal reflector has a maximum diameter designated D. I have empirically determined that in the present antenna system it is preferable to utilize a paraboloid having a relatively small *fm/D* ratio, for example a ratio of the order of .30. For larger ratios, the ellipsoidal sub-reflector member **14** must be placed an excessive distance from the paraboloidal reflector. This greatly increases the difficulties involved in rigidly mounting the ellipsoidal reflector relative to the paraboloidal reflector and also the larger support beams required adversely affect operation of the antenna.

One suitable form of ellipsoidal reflector **14** is machined from a solid aluminum or other conductive metal member. The actual reflector surface **21** of this member is of ellipsoid configuration and is obtained by rotating generating ellipse **21*a*** about its major axis, i.e. the axis through its focii. In the present antenna system, one focus of the ellipse is common with the focus F_o of the parabola and the major axis of the ellipse is coincident with axis **20** of the paraboloid. Consequently, the second focus of the ellipse O_1 also lies on axis **20**. In the present embodiment, this second focal point lies in front of the face of the paraboloidal reflector, i.e. between the paraboloidal reflector and ellipsoidal reflector. It is to be understood, however, that the configuration of the paraboloidal reflector and ellipsoidal reflector could be such that the second focal point falls behind the paraboloidal reflector if desired.

One vertex **22** of the generating ellipse is spaced a distance M beyond the focal point F_o. The distance between the focii O_1 and F_o of the ellipse is indicated by the letter "F." The center of the ellipse, i.e. the mid point between O_1 and F_o is designated O_2. The semi major axis of the ellipse is designated by the letter "*a*" and the semi minor axis is indicated by the letter "*b*." In terms of a Cartesian coordinate system having the abcissa axis coincident with axis **20** and the ordinate axis passing through the center of ellipse O_2, the locus of the ellipse is defined by the equation $X_2^2/a^2+Y_2^2/b^2=1$.

FIGURES 4 and 5 are diagrammatic views corresponding to the vertical sections through the antenna system along axis **20**. (FIGURE 2 can also be considered as corresponding to these views.) FIGURE 4 shows the

ray geometry of the Newtonian unit of the antenna system. More particularly, the Newtonian feed comprises dipole array **17**, the details of which are explained below. Essentially, however, this dipole array has a feed phase center substantially coincident with the parabola focus F_o. In connection with the Newtonian feed, ellipsoidal reflector **21** functions as a ground plane for the dipoles. The spherical phase front emitted by the feed is collimated or converted to plane phase fronts by the paraboloidal reflector surface **11'** in the manner shown in FIGURE 4. Thus, dipole array **17** provides conventional Newtonian feed for parabolic reflector **11**.

FIGURE 5 shows the geometry of the Gregorian unit of the antenna system. As there shown, a suitable UHF or SHF feed, such as diagonal horn **18**, is mounted coaxially with paraboloidal axis **20** at the second focal point O_1 of the ellipse. Radiation from the feed horn strikes the ellipse and is reflected from the ellipse onto the parabola and collimated in the manner shown in FIGURE 5.

Specifically, in order to collimate energy from the feed horn **18** into a beam, the length of all rays from the focal point O_1 to a reference plane QQ must be equal (assuming constant phase velocity for all paths). The ellipsoidal reflector has the property that the lengths of all rays from one focus O_1 to a point on the ellipse and back to the other focus F_o are equal. Similarly, the paraboloidal reflector has the property that the lengths of all rays from the focal point F_o to the reference plane QQ are equal. Thus, since the focal point F_o of the paraboloidal reflector and the second focus F_o of the ellipsoidal reflector coincide and the horn **18** is located at the second focal point O_1 of the ellipse, the necessary conditions are present and the rays from the horn are in fact collimated.

The physical construction of horn **18** is conventional as is the manner of connecting a VHF or UHF transmitter or receiver to the horn. Accordingly, it is not considered necessary to describe the details of construction of this horn member and its connections in the present application.

The details of the dipole array **17** are best shown in FIGURES 6 and 7. As there shown, the dipole array **17** comprises an array of four slot balun-feed one-half wave dipoles **24** with a length to diameter ratio of ten to one. The dipoles **24** are connected in a conventional manner for sum and difference node feeding via four ratrace type hybrids. As is shown in FIGURE 6, the wings **25** of the dipoles are arranged symmetrically relative to paraboloid axis **20**. The dipoles are also spaced a slight distance on the side of focal point F_o remote from ellipsoidal reflector surface **21**. As a result, the dipole feed sum mode phase center coincides substantially with the focal point F_o of the paraboloidal reflector. Connections to the dipole wings **25** are made through feed lines **27** which pass rearwardly through openings formed in reflector member **14**.

One typical installation of the present antenna is used to track a satellite and receive telemetered information from the satellite and its booster. In such use, the Newtonian unit is used to track the booster during the initial stage of a missile launch. Conventionally, a booster transmits signals in the VHF band, i.e. of the order of 220 mc. When the booster and missile pass over the horizon, the Gregorian feed is energized and the antenna directed by drive **13** toward the position in which the satellite is expected to appear at the conclusion of its initial orbit. Telemetry signals from the satellite are usually transmitted on the UHF or SHF band, for example at a frequency of the order of 8000 mc. These signals are efficiently received by the Gregorian unit of the system. It will also be appreciated that the Newtonian and Gregorian units could be used simultaneously if desired. Also, the antenna can be utilized to transmit command signals in the VHF range using the Newtonian feed and in the UHF or SHF ranges utilizing the Gregorian feed.

From the foregoing disclosure of the general principles of the present invention and the above description of a preferred embodiment, those skilled in the art will readily appreciate various modifications to which the invention is susceptible. For example, it is contemplated that the present antenna system can be utilized at still other frequency ranges than those described, e.g. in the infrared range. In any case, however, the diameter of the ellipsoidal sub-reflector must be large with respect to the wave length of the Gregorian feed, i.e. greater than 8λ, so that substantially ray-optic performance is realized in the Gregorian unit as well as in the Newtonian unit of the antenna. It is further contemplated that other elements than the specific dipole array and horn members described can be employed to form the Newtonian and Gregorian feeds. Therefore, I desire to be limited only by the scope of the following claims.

Having described my invention, I claim:

1. An antenna system for simultaneously operating at two frequencies, said antenna system comprising a single paraboloidal main reflector having an axis and a focus located on said axis, an elliposidal sub-reflector having a continuous surface and having one focus coincident with said paraboloidal focus and having a second focus located on said axis, a first feed means directed toward said paraboloidal reflector, said first feed means being disposed at the focus of said paraboloidal reflector to provide a Newtonian feed, second feed means disposed on said axis at the second focus of said ellipsoid for providing a Gregorian feed, said second Gregorian feed means operating at a substantially higher frequency than said first Newtonian feed, said antenna being effective to reflect both said Gregorian feed and said Newtonian feed with substantially optic-ray performance.

2. An antenna system for simultaneously operating at two frequencies, said antenna system comprising a single paraboloidal main reflector having an axis and a focus located on said axis, an ellipsoidal sub-reflector having a continuous surface and having one focus coincident with said paraboloidal focus and having a second focus located on said axis, a dipole array carried by said ellipsoidal sub-reflector intermediate said ellipsoidal sub-reflector and said paraboloidal reflector, said dipole array having a plurality of spaced dipoles having a feed phase center disposed substantially at the focus of said paraboloidal reflector to provide a Newtonian feed, and second feed means disposed on said axis at the second focus of said ellipsoid for providing a Gregorian feed.

3. An antenna system for simultaneously operating at two frequencies, said antenna system comprising a single paraboloidal main reflector having an axis and a focus located on said axis, an ellipsoidal sub-reflector having a continuous surface and having one focus coincident with said paraboloidal focus and having a second focus located on said axis, a dipole array carried by said ellipsoidal sub-reflector intermediate said ellipsoidal sub-reflector and said paraboloidal reflector, said dipole array having a plurality of spaced dipoles having a feed phase center disposed substantially at the focus of said paraboloidal reflector to provide a Newtonian feed, said ellipsoidal sub-reflector functioning as a ground plane for said dipole array, and second feed means disposed on said axis at the second focus of said ellipsoid for providing a Gregorian feed.

4. An antenna system for simultaneously operating at two frequencies, said antenna system comprising a single paraboloidal main reflector having an axis and a focus located on said axis, an ellipsoidal sub-reflector having a continuous surface and having one focus coincident with said paraboloidal focus and having a second focus located on said axis, a dipole array carried by said ellipsoidal sub-reflector intermediate said ellipsoidal sub-reflector and said paraboloidal reflector, said dipole array having a plurality of spaced dipoles having a feed phase center disposed substantially at the focus of said paraboloidal reflector to provide a Newtonian feed, and a diagonal feed horn extending through an opening in the vertex of said paraboloidal main reflector, said diagonal feed horn being disposed on said axis at the second focus of said ellipsoid for providing a Gregorian feed.

5. An antenna system for simultaneously operating at two frequencies, said antenna system comprising a single paraboloidal main reflector having an axis and a focus located on said axis, said paraboloidal main reflector having an f/D ratio of the order of .30, an ellipsoidal sub-reflector having a continuous surface and having one focus coincident with said paraboloidal focus and having a second focus located on said axis, a first feed means directed toward said paraboloidal reflector, said first feed means being disposed at the focus of said paraboloidal reflector to provide a Newtonian feed, second feed means disposed on said axis at the second focus of said ellipsoid for providing a Gregorian feed.

6. An antenna system for simultaneously operating at two frequencies, said antenna system comprising a single paraboloidal main reflector having an axis and a focus located on said axis, an ellipsoidal sub-reflector having a continuous surface and having one focus coincident with said paraboloidal focus and having a second focus located on said axis, a first feed means directed toward said paraboloidal reflector, said first feed means being disposed at the focus of said paraboloidal reflector to provide a Newtonian feed, second feed means disposed on said axis at the second focus of said ellipsoid for providing a Gregorian feed, said second Gregorian feed means operating at a substantially higher frequency than said first Newtonian feed, said antenna being effective to reflect both said Gregorian feed and said Newtonian feed with substantially optic-ray performance, irrespective of the polarization of the feeds.

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