United States Patent

Fletcher et al.

[15] **3,705,406**

[45] **Dec. 5, 1972**

[54] **MULTIPLE REFLECTION CONICAL MICROWAVE ANTENNA**

[72] Inventors: **James C. Fletcher,** Administrator of the National Aeronautics and Space Administration with respect to an invention by; **Robert E. Oliver,** Monrovia, Calif.

[22] Filed: **Nov. 22, 1971**

[21] Appl. No.: **200,682**

[52] **U.S. Cl.** **343/782,** 343/837, 343/915

[51] **Int. Cl.**.....**H01q 19/14**

[58] **Field of Search**.....343/781, 782, 837, 840, 915

[56] **References Cited**

UNITED STATES PATENTS

3,633,209 1/1972 Afifi 343/837

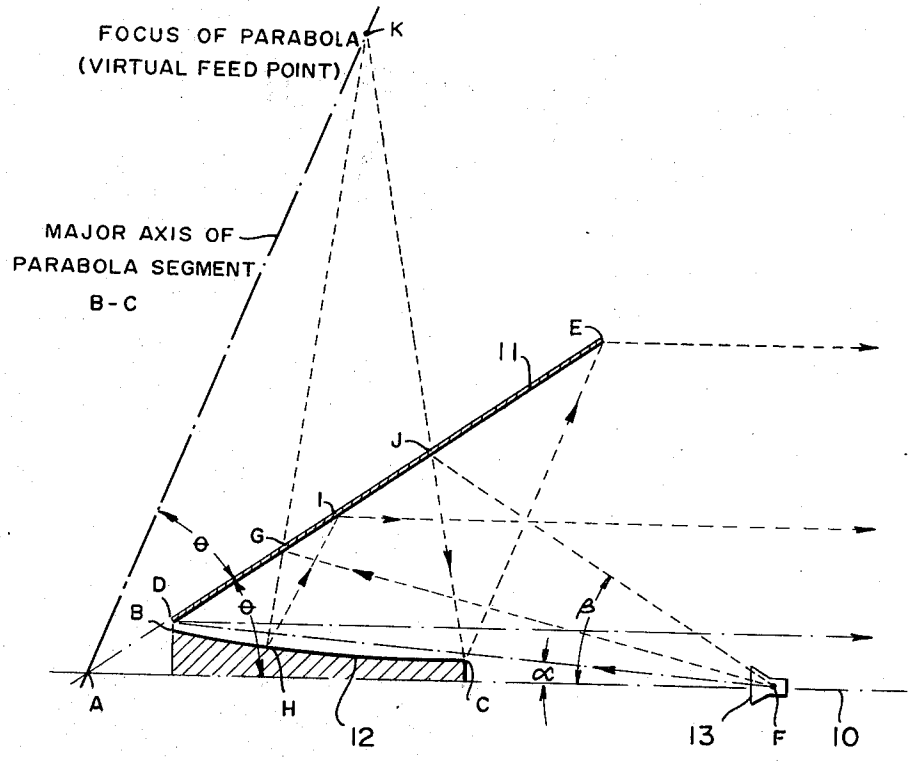
Primary Examiner—Eli Lieberman

Attorney—John R. Manning et al.

[57] **ABSTRACT**

Microwave antennas employing a conical reflector are disclosed with one or two subreflectors to so reflect radiation from a point source feed element that a plane wave front emerges through the antenna aperture with a minimim of blockage of the aperture area by the subreflector(s) and virtually no reflection of radiation back into the feed element.

10 Claims, 5 Drawing Figures



PATENTED DEC 5 1972

3,705,406

SHEET 1 OF 2

FIG. 1

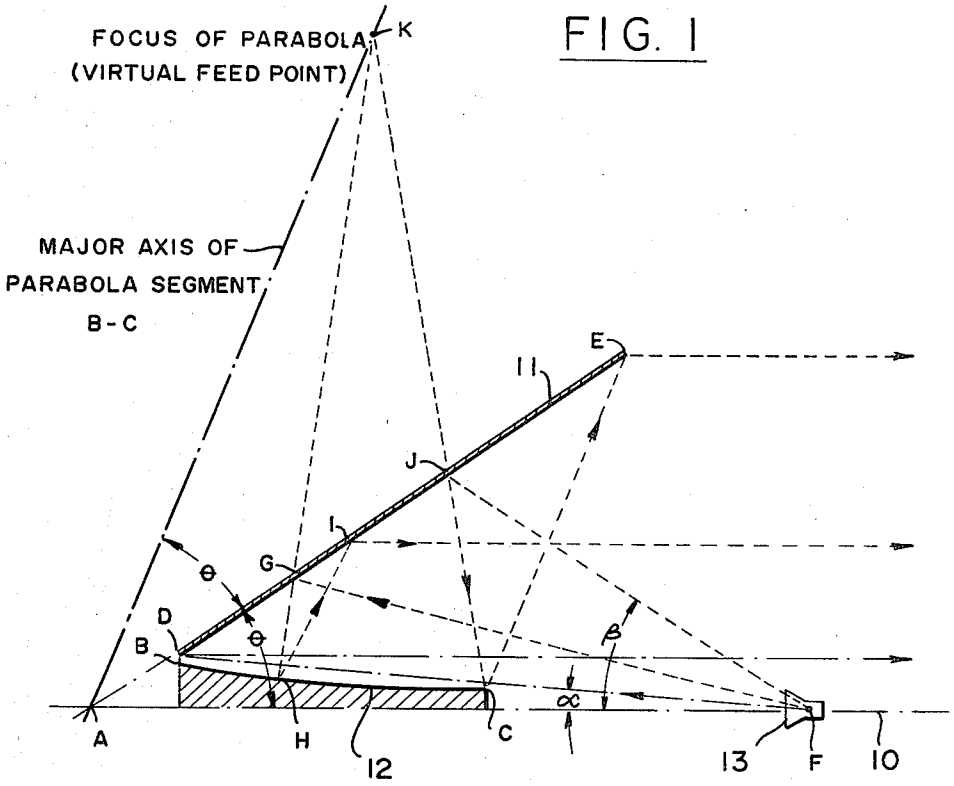
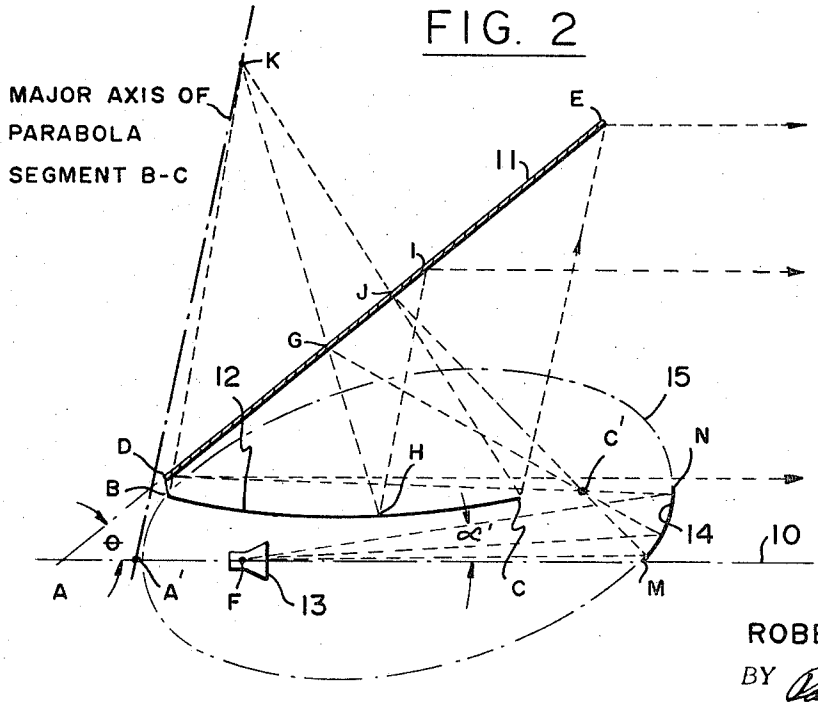


FIG. 2



INVENTOR.
ROBERT E. OLIVER
BY
ATTORNEYS

FIG. 3

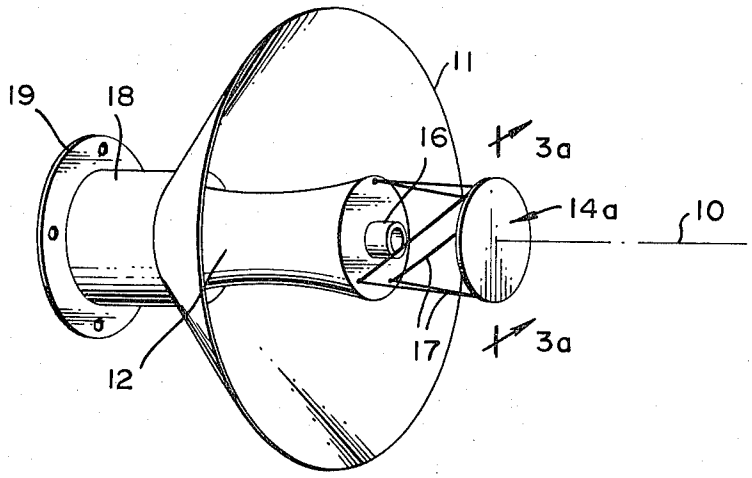


FIG. 3a

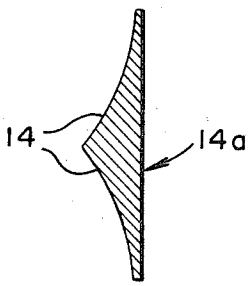
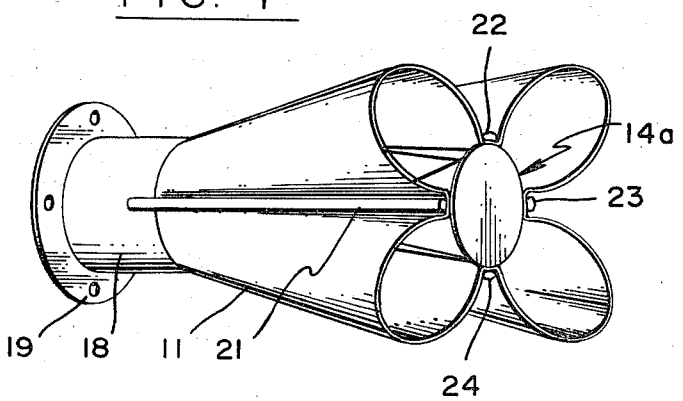


FIG. 4



INVENTOR.
ROBERT E. OLIVER

BY Paul F. McGrail
Monte F. Matt
ATTORNEYS

MULTIPLE REFLECTION CONICAL MICROWAVE ANTENNA

ORIGIN OF THE INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of section 305 of the National Aeronautics and Space Act of 1958, Public Law 85–568 (72 Stat. 435; 42 USC 2457).

BACKGROUND OF THE INVENTION

This invention relates to multiple reflector antennas, and more particularly to antennas utilizing intermediate reflectors to radiate a plane wave front through the aperture of the main reflector.

Antennas employing Cassegrainian and Gregorian telescope principles to couple microwave energy from a feed element to a main reflector have been widely used with various geometrical arrangements. In most, a paraboloidal main reflector is employed with a hyperboloidal or ellipsoidal subreflector.

Similar elements have been proposed for antennas having a conical main reflector. While a conical reflector has several advantages over a parabaloidal reflector, such as ease of manufacture, and furlability for storage, its principal disadvantage is that it requires a subreflector of relatively large diameter (on the order of 0.4 to 0.5 that of the main reflector diameter) as compared to a paraboloidal main reflector which requires a subreflector of relatively small diameter (on the order of 0.2 to 0.3 that of the main reflector diameter).

It would be desirable to provide a multiple reflector antenna having a conical main reflector with an arrangement of one or two subreflectors so disposed about the axis of the conical reflector as to virtually eliminate energy losses due to reflection of energy back into the feed element, and with relatively small diameters for the one or two subreflectors. This would provide the advantages of cost and furlability and avoid the disadvantage of furled size in a conical main reflector antenna.

SUMMARY OF THE INVENTION

In accordance with the present invention, the diameter of subreflector elements for a microwave antenna having a conical main reflector may be significantly reduced by so disposing a subreflector or subreflectors that radiant energy from a point-source feed element is reflected by the conical reflector twice, once into a subreflector, of a shape generated by rotation of a segment of a parabola about the axis of the conical reflector, and then a second time out the aperture of the antenna. By placing the feed element in front of the aperture, only that paraboloidal subreflector is required, and its diameter may be reduced to a minimum on the order of 0.1 that of the main reflector. In order to place the feed element in back of the antenna aperture, an auxiliary subreflector is added having a shape generated by rotation of a segment of an ellipse about the axis of the main reflector. Rays from the feed element facing forward are reflected into the conical reflector. The diameter of the auxiliary subreflector may have approximately the same diameter as the paraboloidal subreflector.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention will best be understood from the following description when read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows diagrammatically an antenna arrangement according to one embodiment of the invention using single subreflector.

FIG. 2 shows diagrammatically an antenna arrangement according to a second embodiment of the invention.

FIG. 3 is a perspective view of an antenna according to the arrangement of FIG. 2, and FIG. 3a is a cross section of an auxiliary subreflector in the antenna of FIG. 3 taken on a line 3*a*–3*a*.

FIG. 4 illustrates one technique for furling the antenna of FIG. 3 to reduce its diameter for storage.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, a first embodiment is shown in a diagram which may be considered to be a cross section of half the geometrical arrangement above the antenna axis **10**. Because the antenna is symmetrical, i.e., the antenna elements **11** and **12** are generated by rotation about that axis, the bottom half is not shown. The element **11**, the main reflector, is a hollow frustrum of a cone with its vertex at A and with a half cone angle θ. The axis of the cone is coincident with the antenna axis. The element **12**, a subreflector surface, is generated by rotation about the antenna axis (through A and F) of an arc B-C of a parabola. The vertex A of the cone and the focus of paraboloidal arc B-C lie on an imaginary cone having a half angle 2θ. The image F of this focus K (as reflected in the main reflector cone) then lies on the antenna axis, and defines the center where a point-source feed element **13** is supported (by struts not shown), such as a conventional microwave horn.

It should be understood that although the preferred embodiments are to be described as transmitting antennas, each may be used for receiving with the same advantages as for transmitting. Therefore, the point-source feed element of each embodiment is to be understood as being connected to a suitable microwave transmitter or receiver. For transmission, the element is the source of radiating energy reflected out of the aperture of the conical main reflector as a plane wave, and for receiving the element becomes the focal point of radiation received. Thus the effective center of the feed is made to coincide with the reflected focal point F of the paraboloidal arc B-C.

For specularly reflective surfaces, a typical ray emanating from feed center F, and forming some angle between α and β with the antenna axis, will be reflected by the main reflector at G, by the subreflector at H, and again by the main reflector at I. This ray then emerges from the antenna parallel to the antenna axis. The ray emerging from the periphery of the cone aperture travels the path F-J-C-E, thus emerging from the antenna parallel to its axis. The ray emerging from the innermost usable part of the cone aperture just grazes the subreflector at C, is reflected by the main reflector at D, by the subreflector at B, and again by the main

reflector near D. The ray then emerges from the antenna in a direction parallel to the antenna axis. Each ray thus experiences three reflections before emerging from the antenna.

For geometrically exact and perfectly reflecting surfaces, it is evident that all optical rays emanating from the feed element between the half angles α and β will emerge from the antenna parallel to the antenna axis. It is also evident that all path lengths of rays from the feed center F to any plane normal to the antenna axis and outside the antenna aperture, i.e. to the right of point E, will be equal. Therefore, a point-source feed element will produce a plane wave front.

It is also evident that the performance of this antenna will be identical to that of a conventional focal-point-feed paraboloidal antenna, using as the generating arc for the main reflector a segment of a parabola having its focus at F. Thus, this multiple-reflection, conical antenna configuration is, in a sense, an optically folded version of a conventional, focal-point-feed paraboloidal antenna. This similarity suggests that it will exhibit some of the disadvantages of the latter. The feed element **13** being relatively far forward from the vertex A of the main reflector **11** requires long feed lines, resulting in feed line losses, and all energy associated with rays emanating from the feed within half angle α is lost because ray paths to the main reflector are obscured by the forward end of the subreflector **12**. Both of these disadvantages can be virtually eliminated by incorporating a modified Cassegrainian feed in accordance with the arrangement of FIG. **2** wherein like elements are referred to by the same reference characters to facilitate understanding how the principles of the arrangement of FIG. **1** are incorporated.

In the arrangement of FIG. **2**, the main subreflector **12** is generated by rotation about the antenna axis of a segment B–C of a parabola, the major axis of which passes through K and A′ and with its focus at K. The reflection in the conical main reflector **11** of this focus K is at C′, which lies above the axis of the antenna, whereas in the arrangement of FIG. **1**, that point is at F, the feed center on the axis of the antenna. Accordingly, an auxiliary subreflector **14** may be used. It's reflecting surface is generated by the rotation of a segment M–N of an ellipse **15** about the antenna axis. The major axis of the ellipse passes through the effective center F of the feed and through the point C′. Therefore, F and C′ are the foci of this generator ellipse **15** shown in dotted line. The circle generated by rotating the point C′ about the antenna axis **10** thus appears as a ring-source since all rays emanating from point F and reflected by the subreflector **14** pass through that ring.

Considering the geometrical properties of ellipses, parabolas, and cones, it is evident that all rays emanating from the feed point F within the half angle α will ultimately emerge from the antenna parallel to the antenna axis, and that path lengths associated with these rays from the feed point F to any plane normal to the antenna axis and to the right of point E are equal. Therefore, a plane wave front is produced as with the arrangement of FIG. **1**.

For geometrically exact and perfectly specularly reflecting surfaces, the performance of this arrangement of FIG. **2** would be identical to that of an antenna with a main reflector surface generated by rotation about the antenna axis of a segment of a parabola with its focus C′, using a point-source feed at F and the auxiliary subreflector **14** as the only subreflector. Accordingly, this arrangement of the multiple reflection conical antenna represents an optically folded version of a more conventional Cassegrainian antenna using a hyperboloidal subreflector.

The multiple reflection conical antenna concepts described with reference to FIGS. **1** and **2** retain many of the advantages of the more conventional conical-Gregorian antennas, i.e. of antennas having a conical main reflector and a conventional Gregorian feed. For instance, the main reflector surface being conical, may be developed from a flat sheet, thus simplifying some aspects of manufacture, assembly, surface distortion measurement, and furling. In addition, proper choices of geometric parameters (e.g. cone angle and focal length of the subreflector surface generator parabola) can provide configurations with very small diameter subreflector elements. For instance, a parametric analysis of the basis configuration shown in FIG. **2** indicates that a ratio of subreflector outer diameter to main reflector outer diameter as small as 0.06 can be realized. This configuration would then produce a direct subreflector blockage of only 0.36 percent of the main reflector projected area (as compared with 16 to 25 percent blockage associated with the more conventional conical-Gregorian concept).

Other important antenna design criteria may, of course, preclude the practical achievement of such low blockage ratios, particularly in smaller diameter or low radio frequency antennas. For instance, the subreflector diameter should, in general, be many (e.g. 10 or more) wave lengths associated with the operating radio frequency. It may be necessary, also, to avoid placing a reflective surface (e.g. point C in FIG. **2**) less than several RF wave lengths from the focal ring (i.e. point C′ in FIG. **2**) of the auxiliary subreflector.

It is recognized that the introduction of additional reflecting surfaces tends to increase performance degradation resulting from deviations of reflecting surfaces from their ideal geometries. This potential disadvantage is, at least partially, compensated for by the relatively small diameters of the subreflectors. In general, the smaller the overall dimensions of a reflecting surface, the easier it is to maintain small manufacturing tolerances and the smaller will be the thermal distortions (for a given thermal environment).

Referring now to FIG. **3**, which illustrates in a perspective view an antenna according to the design of FIG. **2**, a point-source feed element comprised of a standard horn-type feed is mounted within the paraboloidal reflector **12**. The latter is turned on a lathe and drilled along the turning axis to provide what is essentially a hollow cylinder with a paraboloidal outer surface. The aperture of that hollow cylinder may be extended by a short cylindrical section **16** to confine the cone of radiation from the point-source feed element to the ellipsoidal reflector **14**. The latter may be turned on a lathe or cast and polished in the shape shown in FIG. **3***a* which illustrates a section of the reflector **14** taken along a diameter.

Three equally spaced points on the end of the reflector **12** are connected to three equally spaced points on the reflector **14** by six thin rods **17**, as shown to support

the reflector 14 in front of the antenna aperture. The reflector 12 is itself supported by a short cylindrical section 18 connected to a mounting plate 19. The latter is adapted to be connected to a mechanism on a vehicle or space craft for directing the antenna. The cylindrical section 18 is hollow to permit a wave guide or coaxial cable to be connected to the point source feed element within the reflector 12. In practice that section may be turned on a lathe as an integral part of the reflector 12. The smaller cylindrical section 16 may also be turned as an integral part at the same time. After drilling the aperture through that section 16 and the reflector 12, a larger hole is drilled through the section 18 to permit the feed element to be inserted and fastened in place. If a waveguide is used, the feed element may be simply supported at the end of the waveguide by the waveguide itself. The waveguide would then be secured in place by brackets at the rear of the mounting plate 19.

FIG. 4 illustrates one manner in which the main reflector 11 may be furled using four struts 21 to 24, each hinged at the section 18 to permit them to be drawn up against the reflector 14. The struts may be slightly longer than shown to permit them to extend beyond the edge of the conical reflector 11. Then they may be held in the furling position by a split ring, or the like. If the struts are moved into the furling position by hydraulic actuators, such a retaining device would not be required.

Other embodiments of this multiple reflection conical antenna concept are obvious from the embodiment of FIG. 2 and its similarity to a conventional Cassegrainian antenna. For example, instead of using an ellipsoidal auxiliary subreflector which reflects back from in front of the antenna into the main reflector as shown in FIG. 2, a crossed-ellipsoidal subreflector may be used to reflect rays from the point source across the antenna axis into the conical reflector. Still other embodiments may employ crossed or uncrossed hyperboloidal auxiliary subreflectors in place of the subreflector 14 shown, in each case generating the subreflector by revolving a segment of a hyperbola where that hyperbola has its axis passing through the feed center and a point offset from the antenna axis in a manner similar to the offset at the point C in FIG. 2. However, the uncrossed ellipsoidal subreflector of FIG. 2 is preferred over the crossed hyperboloidal subreflector because the length of the paraboloidal subreflector 12 would have to be shortened sufficiently to avoid interfering with cross-reflected rays, thus imposing design limitations on the half angle of the cone and the size of the aperture. The same is true of the crossed hyperboloidal arrangement for the same reason.

The half angle θ of the conical reflector is established in conjunction with the orientation of the paraboloidal segment from which the subreflector 12 is generated such that a ray directed into the conical reflector which just clears the front edge of the subreflector 12, is reflected down onto the subreflector, from there onto the conical reflector, and from there emerges as a ray parallel to the cone axis. When an auxiliary subreflector is employed in front of the paraboloidal reflector 12 (in order to mount the point-source feed element behind the antenna aperture), the emerging ray thus reflected must just clear the subreflector 14 as shown in FIG. 2. The leading edges of the conical main reflector 11 and the parabaloidal subreflector 12 are then set to just accommodate a reflected ray from the conical reflector parallel to the antenna axis at maximum diameter. An uncrossed hyperboloidal arrangement for the subreflector 14 instead of the uncrossed ellipsoidal shape shown would impose further limitations on the length of the paraboloidal subreflector 12 relative to the diameter of the hyperboloidal subreflector and consequently decrease the ratio of the diameter of the antenna aperture to the diameter of the hyperboloidal reflector. Accordingly, the arrangement using an ellipsoidal subreflector shown in FIG. 2 is preferred over this as well as the other possible arrangements. However, inasmuch as it is recognized that modifications and variations falling within the spirit of the invention will occur to those skilled in the art, it is not intended that the scope of the invention be determined by the disclosed exemplary embodiments, but rather should be determined by the breadth of the appended claims.

What is claimed is:

1. A microwave antenna comprised of

a main reflector having an inside surface in the shape of a hollow frustum of a cone for reflecting incident rays into parallel rays which are parallel to the axis of said cone and which emerge from said reflector as a plane wave front, and

means for irradiating said main reflector surface with microwave rays from a point source at such angles of incidence that they are reflected by said main reflector surface as rays parallel to said axis with a plane wave front, said means including a subreflector having a surface produced by rotating a segment of a parabola about said cone axis, said segment being oriented with respect to said main reflector so that initial rays reflected by said main reflector onto said subreflector are reflected by said subreflector back onto said main reflector surface to be re-reflected therefrom as parallel rays with a plane wave front.

2. A microwave antenna as defined in claim 1 wherein said means for irradiating said main reflector surface with initial rays comprises a point-source feed element on said cone axis in front of the antenna aperture defined by the edge of said main reflector surface of largest diameter.

3. A microwave antenna as defined in claim 1 wherein said means for irradiating said main reflector surface with initial rays comprises a point-source feed element on said cone axis in back of the antenna aperture defined by the edge of said main reflector surface of largest diameter, and subreflecting means in front of said antenna aperture for reflecting rays from said element directly onto said main reflector surface for double reflection therefrom as said parallel rays with a plane wave front.

4. A microwave antenna as defined in claim 2 wherein said subreflecting means comprises a subreflector having a surface produced by rotating a segment of an ellipse about said cone, said ellipse having foci at the point of feed from said element and at a focus of said segment of said parabola as reflected from in back of said main reflector to a point in front of said main reflector.

5. A microwave antenna as defined in claim 4 including means for furling said main reflector by moving a plurality of radial sections thereof evenly spaced inwardly.

6. A multiple-reflector antenna with minimum aperture blockage of radiation emanating from a point source into parallel rays with a plane wave front, comprised of

a main reflector having an inside reflecting surface in the shape of a cone the axis of which defines the axis of the multiple reflector antenna,

a subreflector disposed inside of said cone, said subreflector having an outside reflecting surface facing said inside reflecting surface of said cone, said subreflector being of a form generated by revolving a segment of a parabola about said axis of said cone, where said parabola has its focus outside of said cone so positioned that rays appearing to emanate from said focus as a feed point are reflected by said subreflector onto said main reflector for reflection by said main reflector into parallel waves with a plane wave front, and

means for irradiating said main reflector with rays everywhere appearing to emanate from a point corresponding to said focus reflected from outside of said cone to inside of said cone.

7. A multiple-reflector antenna as defined in claim 6 wherein said irradiating means comprises a point source feed element on said cone axis radiating directly back into said main reflector from a point outside and in front of said cone which is a mirror image of said focus of said parabola a segement of which is rotated the generate the form of said subreflector.

8. A multiple-reflector antenna as defined in claim 6 wherein said irradiating means comprises a point source feed element on said cone axis and inside of said main reflector, said element radiating directly out of said main reflector, and an auxiliary reflector in the direct path of radiation from said point source radiating element for reflecting radiation back into said main reflector as though emanating from an infinite number of apparent point source elements in a ring about said cone axis, each of said infinite number of point source elements being a point in front of said cone which is a mirror image of said focus of said parabola, a segment of which is rotated to generate the form of said subreflector, said main reflector functioning as a reflecting surface to form said mirror image.

9. A multiple reflector antenna as defined in claim 8 wherein said auxiliary reflector has a reflecting surface, facing into said main reflector and toward said radiating point source element, which is generated by revolving a segment of an ellipse about said axis of said cone, one of the foci of said ellipse being at said radiating point source element and the other one at one of said infinite number of apparent point source elements.

10. A multiple reflector antenna as defined in claim 9 wherein said subreflector is formed on the outside of a cylinder and said radiating point source element is mounted in a coaxial cylindrical cavity in said cylinder.

* * * * *