United States Patent

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[54] **COMPACT SCANNING RADAR ANTENNA**

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[73] Assignee: **The United States of America as represented by the Secretary of the Army**

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[52] **U.S. Cl.** **343/761**, 343/786, 343/840, 343/914

[51] **Int. Cl.**.....**H01q 13/00**

[58] **Field of Search**.....343/781, 786, 912, 915, 761, 343/840, 914

[56] **References Cited**

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3,165,747	1/1965	Wales	343/914
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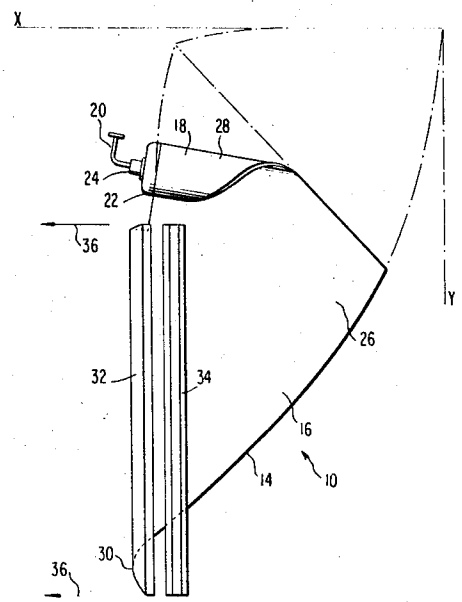
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[57] **ABSTRACT**

Disclosed are radar sectoral horn antennas of the rolled and folded parallel plate type having two internal reflectors which makes possible a more compact construction. The double fold or double reflector construction is applicable to sectoral horns having an *f/d* ratio greater than one and the reflectors may be straight or curved. The horns may be provided with a dielectric, geodesic or wave guide lens and by combining two orthogonally related antennas, three dimensional scanning is possible.

2 Claims, 8 Drawing Figures



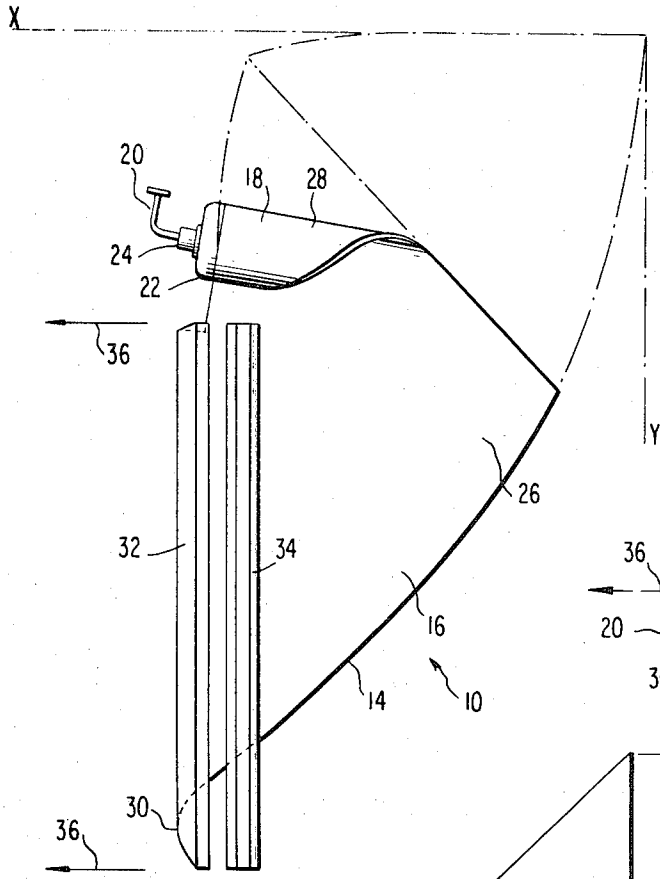


FIG. 1

FIG. 2

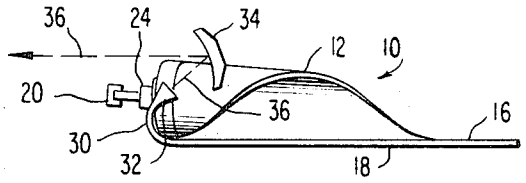


FIG. 4

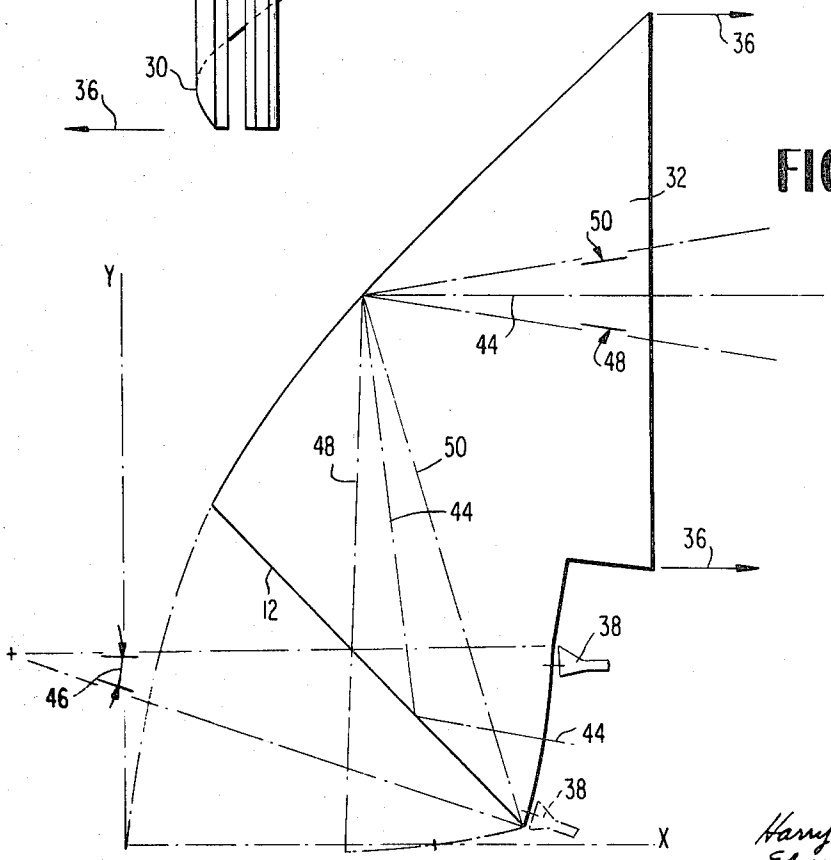
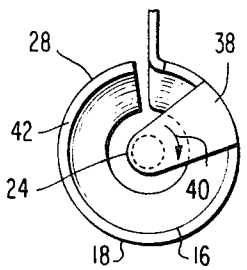


FIG. 3



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FIG. 6

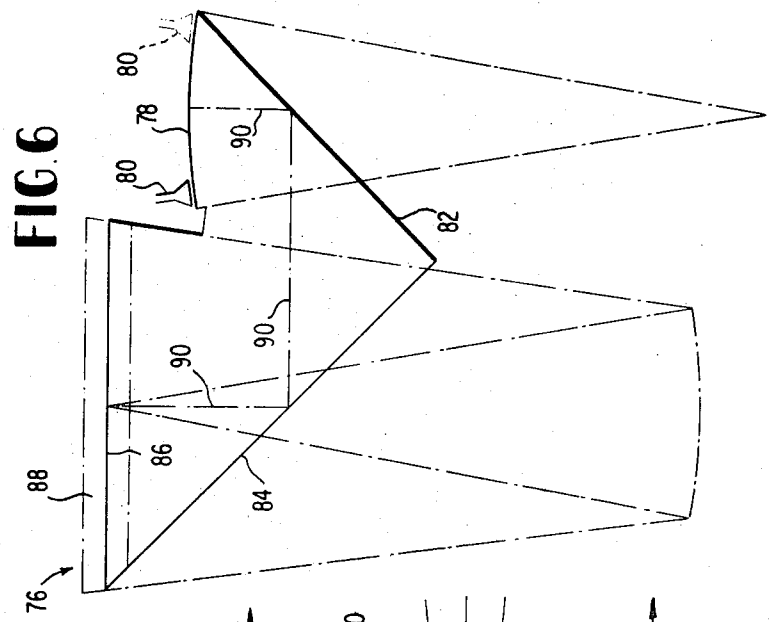


FIG. 7A

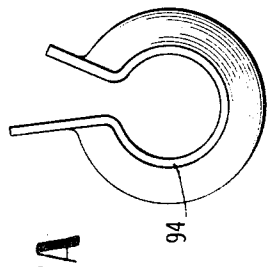


FIG. 5

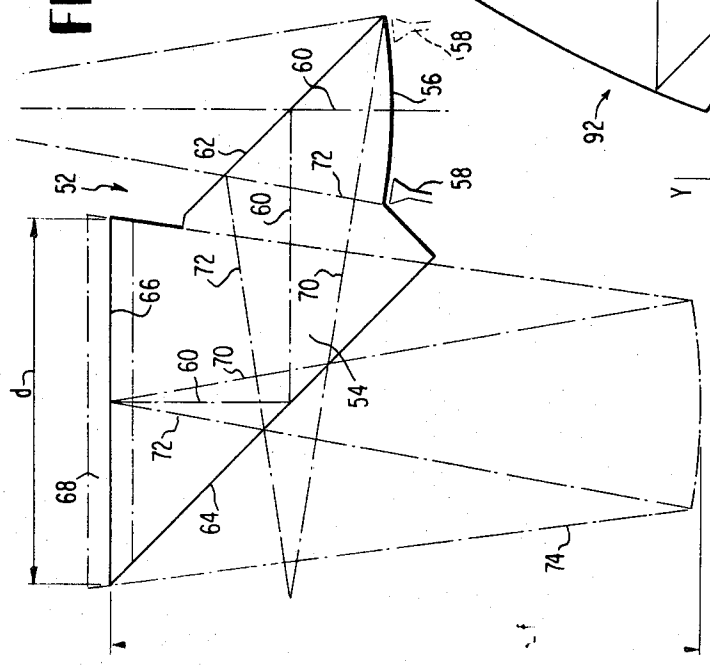
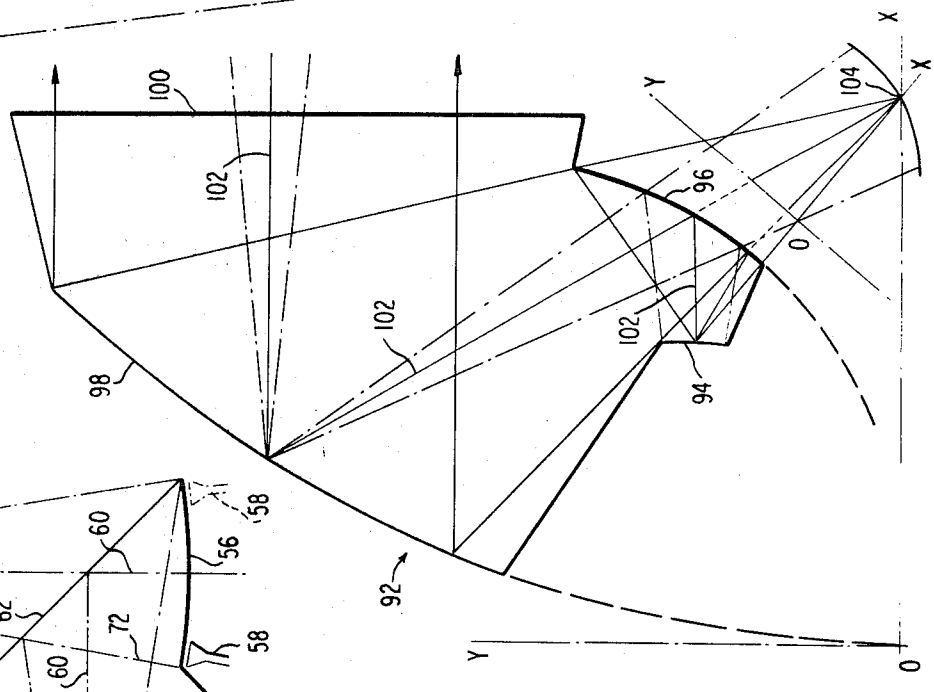


FIG. 7



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COMPACT SCANNING RADAR ANTENNA

This invention relates to a double fold or double internal reflector antenna which by incorporating a pair of internal reflectors make it possible to construct a much more compact antenna which retains the desirable features of larger physical constructions. The antenna finds particular utility as a radar antenna useful in tracking range and/or angular position of airplanes, missiles, satellites, or other air or space borne bodies.

Radar antennas have been used for many years in fire-control systems and also in other applications requiring range and angle detection of space objects. Early radar antennas utilized motion of the entire antenna to achieve volume coverage. Subsequently, constructions appeared that provide line scanning utilizing oscillatory feed motion. Some of these employed large, trapezoidal, parallel plate sectoral horns which were quite large and cumbersome and as a consequence were difficult to manufacture and operate.

In U.S. Pat. No. 2,585,562, to W. D. Lewis, there is disclosed a sectoral horn antenna which employs a much more mechanically desirable nonoscillatory or rotary feed system and one in which the sectoral horn is bent or folded into a much more compact construction. This antenna operates in the transverse electric and magnetic (TEM) wave mode and the input end of the trapezoidal horn is formed annularly so that a small feed horn can be continuously rotated at the annular orifice. Rotation of the feed horn at the input orifice results in a repetitive angular displacement of the beam emanating from the large output aperture which scans a sectoral volume of space. In operation, the angular position of a target is determined as a function of the angular position of the horn, the horn angle being proportional to the beam swept angle. That is, electromagnetic energy is reflected (or emitted) from the target, received by the antenna, and focused at a point in the annular orifice where it is picked up by or enters the feed horn each time it passes the point during rotation. Usually, electronic tracking circuitry is employed to measure the angle as a function of elapsed time between a scan start position pulse provided by a motion transducer on the scanner and the "center" of the energy reflected from the target. Range is determined by the time required for the microwave pulses to propagate to the tracked object and back to the receiver. In order to collimate the outgoing energy, a dielectric lens (similar to an optical lens) is placed in the sectoral horn near the exit aperture.

The present invention is directed to a scanning radar antenna of generally similar parallel plate construction utilizing a trapezoidal sectoral horn but one which is of improved and more compact construction. The present invention is based on the fact that it has been found that by increasing the ratio of sectoral horn focal length to exit aperture width, it is possible to incorporate an additional fold or additional internal reflector into the sectoral horn, thus reducing the flat plate area of the horn before rolling by as much as 50 percent or more compared to the uninterrupted flat plate area. The double fold construction of the present invention retains the desirable continuous rotary feed features of prior single fold antennas but, in addition, provides a longer focal length in design volumes, improved radar resolution, less severe lens contours, new configurations which permit easier fabrication and dismantling for inspection and repair, and makes possible a compact construction capable of scanning a sectoral volume of space. In addition, by incorporating curved reflectors, it is possible in some instances to eliminate the need for a lens near the exit aperture of the horn.

It is therefore one object of the present invention to provide an improved scanning radar antenna.

Another object of the present invention is to provide a scanning radar antenna that is more compact and therefore more easily manufactured and operated.

Another object of the present invention is to provide a radar scanning antenna having a pair of internal reflectors.

Another object of the present invention is to provide a compact radar scanning antenna which makes possible longer focal lengths in a predetermined volume.

Another object of the present invention is to provide an improved compact scanning radar antenna incorporating one or more curved reflectors.

Another object of the present invention is to provide a radar antenna construction which makes possible volume or line scanning of space utilizing a continuously rotating feed horn.

These and further objects and advantages of the invention will be more apparent upon reference to the following specification, claims, and appended drawings, wherein:

FIG. 1 is a plan view of a rolled parallel plate double reflector antenna constructed in accordance with the present invention;

FIG. 2 is an elevational view of the antenna of FIG. 1;

FIG. 3 shows the annular feed aperture of the antenna of FIGS. 1 and 2;

FIG. 4 is a plan view of the antennas of FIG. 1–3 before rolling and folding and illustrates the two internal antenna reflectors;

FIG. 5 is a development view similar to that of FIG. 4 showing an oblique double reflector antenna with a pair of straight reflectors and a rear scanner;

FIG. 6 is a similar development view of an antenna incorporating a pair of inner reflectors having a front scanner;

FIG. 7 is a development view of a further modification showing an antenna with a pair of curved reflectors;

FIG. 7A shows the inlet aperture of FIG. 7 after rolling;

Referring to the drawings, FIGS. 1 and 2 illustrate an antenna, generally indicated at **10**, constructed in accordance with the present invention. In this embodiment, the antenna takes the form of a rolled parallel plate antenna having a linear internal reflector **12** and a parabolic internal reflector **14**. The antenna is formed from a pair of parallel conductive metal plates **16** and **18** spaced to define an air gap between them equal to one-half the operating wave length or less. The antenna, depending upon the dimensions, may be operated at any suitable microwave or radar frequency, such as K-band, X-band, S-band, L-band, or the like. A typical spacing between parallel plates may be on the order of one-fourth inch to 1 inch, but for TEM mode operation not to exceed one-half wave length. The antenna comprises wave guide feed line **20** adapted to be electrically coupled to a conventional transmitter-receiver for transmitting electromagnetic energy from the antenna

and receiving reflections from a target in a well-known manner. Wave guide **20** is connected to a rotating scan head **22** by way of a rotary joint **24**. Energy from the wave guide **20** passes through the scan head **22** into the sectoral horn, generally indicated at **26**, formed by the spaced parallel plates **16** and **18**. A portion of the horn adjacent the feed head is rolled into a cone, as illustrated at **28**. The plates are joined along their edges **12** and **14** to form a strip so that the microwave energy is reflected first from edge **12** and then from edge **14** as it passes through the sectoral horn. The parallel plates are illustrated as cylindrically curved or bent, as at **30**, and terminate in an outwardly flared edge or end **32** forming an outlet aperture for electromagnetic energy transmitted from the feed line through the antenna. In the preferred construction, the energy exiting from the antenna (and similarly reflected energy from the target) is collimated along the longer dimension of the aperture by a curved external reflector **34**. Energy emanating from the antenna is indicated by the arrows **36**.

FIG. **3** illustrates the feed arrangement of the antenna of FIGS. **1** and **2** in more detail and shows the rotary joint **24** coupled to feed horn **38** which is continuously rotated, as illustrated by the arrow **40** in FIG. **3**, in the conventional manner. Feed horn **38** is located within the scan head **22** of FIG. **1** and includes a 90° cylindrical bend (not shown) so that energy emanating from the feed horn enters the annular inlet aperture **42** between the portions of plates **16** and **18** forming feed cone **28**.

FIG. **4** is a development view of the parallel plates of the antenna of FIGS. **1–3** before the parallel plates are bent and rolled. The feed horn **38**, which if desired FIG. **4**, be made slightly asymmetric to compensate for illumination asymmetry, scans along the inlet aperture **42**. In development, the edge of the inlet aperture is of arcuate configuration forming the arc of a circle which when rolled into the shape of a cone, as illustrated in FIGS. **1–3**, lies in a plane adjacent the rotary feed horn. The center of the electromagnetic energy from the feed horn, as illustrated by the ray line **44**, impinges upon electrically conductive edge **12** where it is reflected and propagates between the plates to impinge upon the electrically conductive edge **14**. The electromagnetic energy is again reflected from edge **14** and passes out of the antenna through output aperture **32**. In development, that is before bending, edge **12** forms a linear secondary reflector and edge **14** forms a parabolic primary reflector. After bending and rolling, the propagation of the microwave energy through the antenna is in a sense the same, that is, it is reflected from both linear reflector **12** and parabolic reflector **14**. The scan angle is illustrated at **46** in FIG. **4**. Lines **48** and **50** indicate approximately the angle of the scanned sector. By incorporating a curved internal reflector, such as the parabolic reflector **14** in FIGS. **4**, it is not necessary to provide a lens in the antenna of FIGS. **1–3** since focusing is achieved by the parabolic reflector **14** across the narrower dimension of the output energy. While FIGS. **1–4** have been described in conjunction with energy transmitted outwardly from the antenna, it is understood that reflected energy from the target passes through the antenna in the same manner but in the opposite direction from outlet aperture **32** to feed aperture **42**. In order to retain the precise electromagnetic characteristics of the development of FIG. **4**, it is necessary that the sectoral horn be bent, curved or rolled into developable geometric shapes, such as cones and cylinders, without distorting the input and output edges or stretching the median surface between conducting sheets.

FIG. **5** is a development view of a modified antenna constructed in accordance with the present invention. It is understood that the antenna of FIG. **5** in its final configuration is rolled and folded in the manner of the antenna of FIGS. **1–3** so as to be compact and to have an annular input aperture. The antenna of FIG. **5** is an oblique double reflector parallel plate antenna with rear scanner and incorporates a pair of linear reflectors.

The antenna of FIG. **5** again comprises a pair of parallel conductive plates, one of which is indicated at **54**, and the antenna **52** has an arcuate inlet aperture **56** which, when rolled into a cone, presents a planar aperture scanned by a continuously rotating feed horn **58**, in all respects similar to the rotatable feed horn previously described. In FIG. **5**, the central ray line **60** passes through the center of the input aperture **56** and impinges on a secondary reflector **62** which is a straight reflector formed by one edge of the antenna. The central ray then passes between the parallel plates where it is again reflected off a second straight reflector or edge **64**, forming the primary reflector of the sectoral horn. From here the central ray **60** passes through an output aperture **66** which includes a microwave lens area **68**. Since the reflectors **62** and **64** in this embodiment are straight, they provide no focusing and it is desirable to provide a lens **68**, which may be formed of a plastic or dielectric lens, metal plate, but is preferably in the form of a geodesic lens. This may consist of the conventional parabolic-bulge or the semi-paraboloid-of-revolution lenses, for examples.

The limits corresponding to the extreme sweep positions of the feed horn **58** are illustrated at **70** and **72** in FIG. **5**. The scan center for feed horn motion is preferably located at the geometric or optical center of the lens **68**.

All the double reflector horns of the present invention may be thought of as originally derived from a trapezoidal or sectoral parallel plate horn, as indicated by dashed lines at **74** in FIG. **5**. The horn may be further thought of as this trapezoid twice folded with the overlapping or coextensive portions of the original trapezoid omitted. Thus, as seen from FIG. **5**, the overall length and volume of the sectoral horn is substantially reduced by at least half without sacrificing the original focal length given by the dimension *f* in FIG. **5** which extends from the center of the entrance aperture to the center of the lens if a lens is employed. The angle of scan is determined by the circular or arcuate curvature of the input aperture. The longer dimension of the output aperture is given by the dimension *d* in FIG. **5**. It has been found that for sectoral horns having a ratio *f/d* greater than 1, that two internal reflectors may be employed to substantially decrease the size of the antenna and increase its compactness. In the present invention, the preferred range for the *f/d* ratio is on the order of 1.2 to 1.7.

FIG. 6 is a development view of a modified double reflector antenna constructed in accordance with this invention. The antenna illustrated in FIG. 6 is an oblique double reflector plate antenna with two straight reflectors similar to that shown in FIG. 5, but provided with a front instead of the rear scanner illustrated in FIG. 5. In FIG. 6, the antenna is generally indicated at 76 and comprises an arcuately curved inlet aperture 78, rotary feed horn 80, straight secondary reflector (second fold) 82, a primary straight reflector (first fold) 84, output aperture 86, and lens area 88. As before, inlet aperture 78 forms a part of a rolled cone so that the arcuate aperture when rolled lies in a single plane. The central ray line 90 in FIG. 6 is first reflected from reflector 82 and then reflected from reflector 84 to pass out through the center of the lens 88.

FIG. 7 shows a further modified embodiment and is a development view of a "half-cassegrain" 2-reflector parallel plate antenna in which both reflectors are curved. The antenna comprises a concavely, rather than convexly, curved input aperture 94 forming a part of the antenna 92 and the annular nature of this aperture after rolling into a cone is illustrated in FIG. 7A. A first reflector is formed by edge 96 curved into the segment of hyperbola and a second reflector is formed by edge 98 having a parabolic curvature. The output aperture is illustrated at 100. Central ray 102 these reflectors and is emitted through the center of the outlet aperture 100. In this embodiment, the feed horn acts as a point source feed at the hyperbola reflector focus and the focus of the parabola 98 is at the center of the virtual scan arc as illustrated at 104 (common focus for the parabola and hyperbola). The second hyperbola focus is at the center of arc 94. It is seen that as a result of the geometric relationships involved in this embodiment, a more compact scanner is achieved in addition to other advantages which are common to the various designs. Since size of the scan head is a limiting factor in determining scan rate, higher rates are realizable with this arrangement.

The focal lengths of the antennas may be for example 10 or 20 feet or more and, depending on size and shape, the antennas may be used over a wide range of microwave frequencies. Scan repetition rates of up to 30 Hz or greater can be obtained with peak power transmission in the megawatt region. Since the output beam is line scanned, two dimensions are measurable with a single antenna within the space sector. For example, range and azimuth angle. To make cross angle measurements, such as elevation, a second antenna may be used. The antenna beam may be either a pencil beam or may be the characteristic fan beam shape. Lenses of the geodesic, metal plate or dielectric types may be employed to provide the collimation in the narrow angle dimension of the fan or pencil beam and external reflectors may be used to provide the desired amount of collimation in the broad angle dimension. The horn may be rolled up or curved with discretion into developable geometric shapes, such as cones and cylinders, so long as the input and output edges are not distorted and so long as stretching of the median plane is not involved.

The invention may be embodied in other specific forms without departing from the spirit and essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

I claim as my invention:

1. A sectoral horn antenna having rolled and folded paralleled spaced plates comprising:
   - an inlet aperture formed by a rolled portion of the plates;
   - a first internal linear reflector formed by a folded strip joining the edges of the rolled portion of the plates,
   - a second internal substantially parabolic reflector formed by a folded strip joining the edges of the flat portion of the plates; and
   - an outlet aperture formed in a further rolled portion of the plates.

2. The structure of claim 1 wherein the antenna has a focal length identified as f, and wherein the width of the outlet aperture is identified as d, the ratio f/d being greater than one.

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