United States Patent [19] **Grenzeback**

[11] **3,740,755**

[45] **June 19, 1973**

[54] **MICROWAVE ANTENNA WITH RADOME**

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[51] **Int. Cl.** **H01q 19/12**

[58] **Field of Search** 343/840, 872, 873, 343/915

[56] **References Cited**

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[57] **ABSTRACT**

A microwave antenna having a parabolic reflector with a confocal parabolic radome. The coincident foci of the reflector and radome cause reflections from the latter to be incident upon the reflector in the same direction as the energy directly incident thereon from the feed. The antenna is integrally formed in nestable segments each comprising portions of the reflector, the radome and any interconnecting shroud.

14 Claims, 5 Drawing Figures

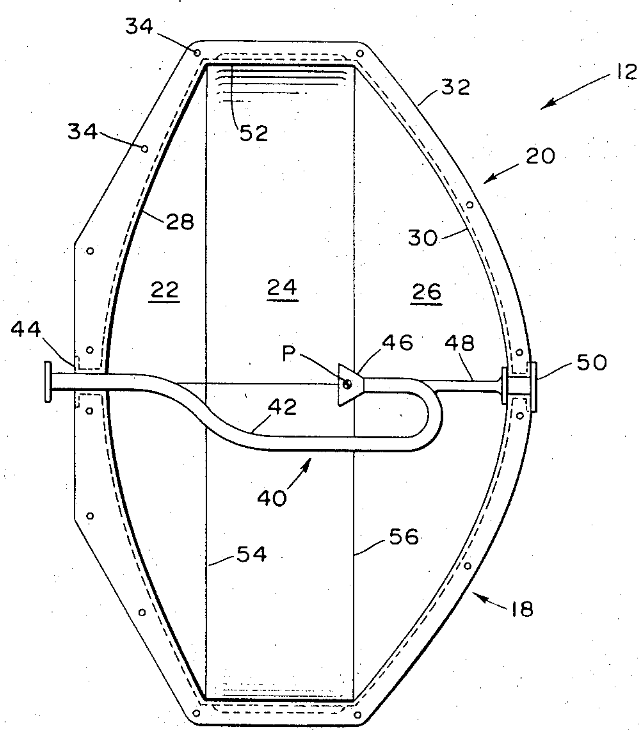
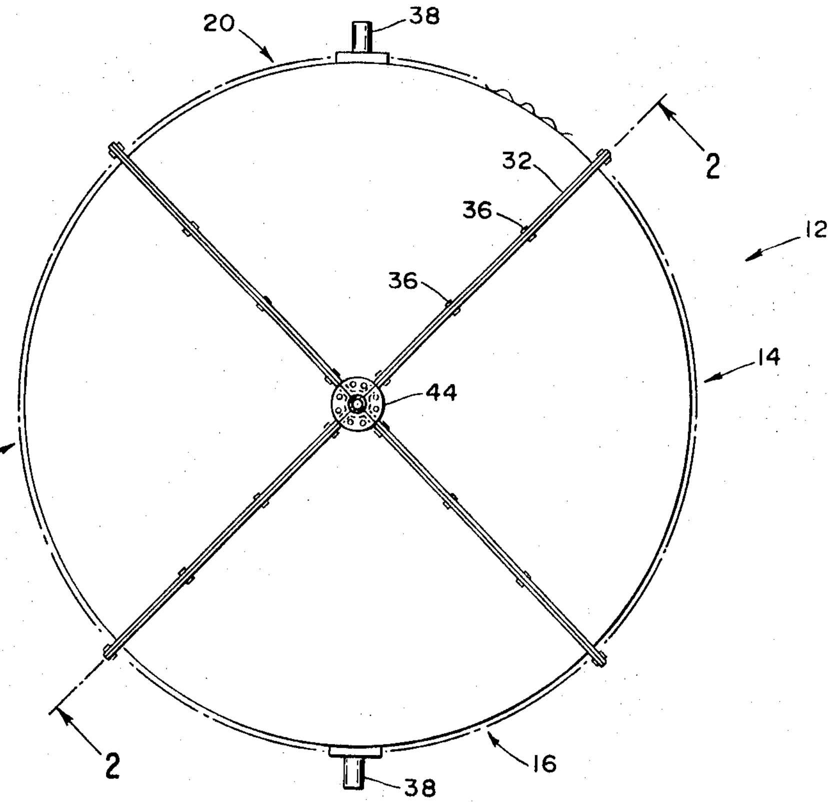


FIG. 1


20
38
2
32
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12
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14
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18
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16
38

FIG. 2

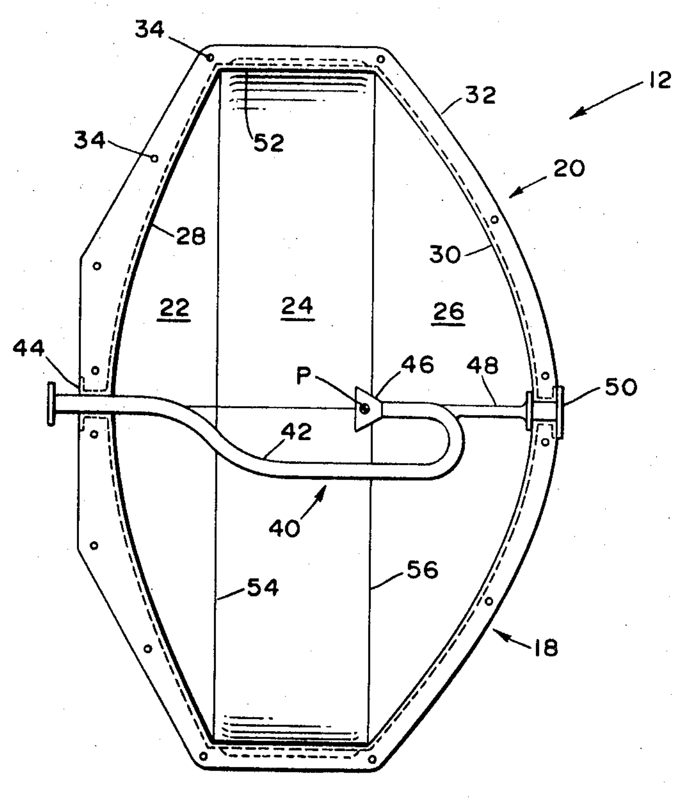
34
12
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FIG. 3

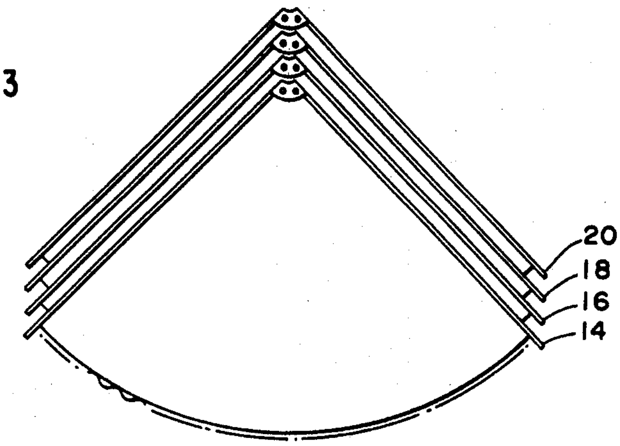


FIG. 4

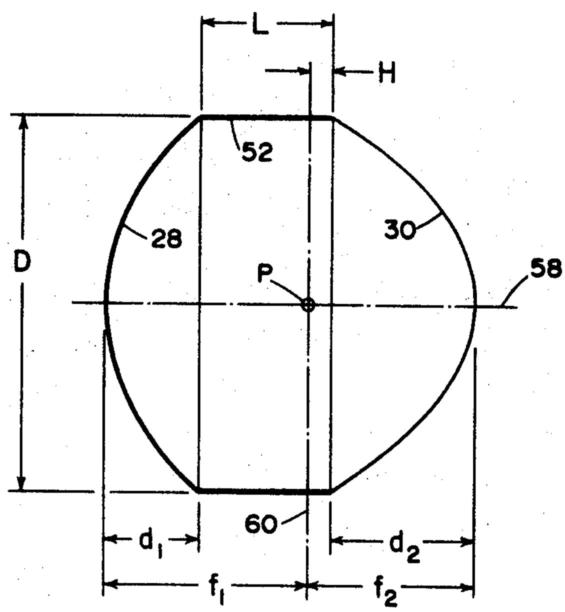
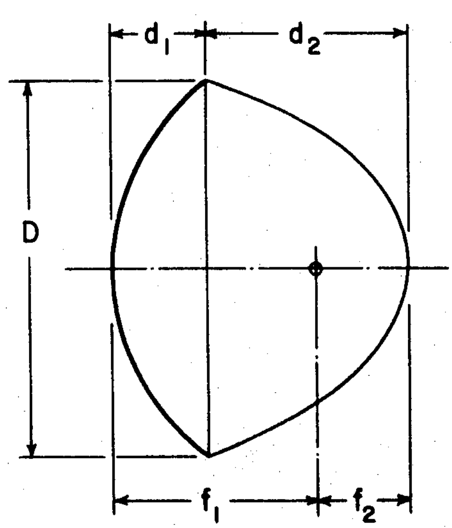


FIG. 5



MICROWAVE ANTENNA WITH RADOME

BRIEF SUMMARY OF THE INVENTION

This invention relates generally to microwave antennas, and more particularly to antennas having radomes. For protection of the parabolic electrically conductive inner surface of the reflector against damage including icing and other weather effects, it is customary to provide an electrically nonconductive radome of curved shape to form an enclosure with the reflector. Radomes in common use are frequently of conical shape with rounded noses. Antennas having radomes are constructed with or without shrouds, which are usually of cylindrical shape and having electrically conductive inner surfaces. A shroud is useful to prevent stray reflections and leakage of energy at the annular rim of the reflector, including diffraction effects and "crosstalk" between closely adjacent antennas having substantially the same directions of transmission.

Reflector-type antennas in common use frequently have a focal length which is approximately four-tenths of the diameter measured at the annular peripheral rim of the reflector. The aperture size of the antenna, which in the case of a paraboloidal reflector corresponds to its diameter, determines the radiating area of the antenna which in turn determines its gain. With large antennas equipped with radomes, difficulties arise from problems of fabrication and shipping because of the large volume of the assembled enclosure and the necessity to provide structural rigidity and integrity both in transit and in use.

Difficulties are also commonly encountered as a result of the fact that the radome is only imperfectly transparent to incident microwave energy, and in practice it may reflect as much as 20 percent of such energy. This results in a reduction in transmission efficiency. Moreover, the reflections from the radomes commonly employed have destructive interference with the signal in a manner which is a function of both the geometry or shape of the randome and the frequency of the signal. Therefore, as a practical matter, the design of the antenna and radome is complicated and the end use is restricted by reason of this destructive interference. In other words, while the reflector itself is an inherently broadband or frequency-independent device, its combination with the usual radome results in making it more frequency-dependent.

The improved antenna embodying this invention is characterized by a predetermined structural relationship between the inner reflector and radome surfaces. In the preferred embodiment the reflector and radome are both parabolic in shape with coincident foci, the feed being located to radiate energy from the common focal position.

As a means of fixing the reflector and radome surfaces in accurate spacial relationship, these parts preferably comprise portions of an integrally formed, segmental structure, whereby the segmental portions are nestable for space conservation in shipping and the antenna is assembled at the site of installation by joining the segments to form a complete enclosure.

An antenna according to this invention may be constructed with or without a shroud, depending upon end use considerations. If a shroud is employed, each integral antenna segment includes a shroud portion interconnecting corresponding reflector and randome portions.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a back elevation of an antenna embodying the invention.

FIG. 2 is a side elevation in section taken on line 2—2 of FIG. 1.

FIG. 3 is an elevation showing a number of antenna segments nested for storage and shipment.

FIG. 4 is a schematic diagram corresponding to the embodiment of FIGS. 1 and 2, for illustrating the spacial relationship of the several parts.

FIG. 5 is a schematic diagram similar to FIG. 4 and illustrating an alternative embodiment without a shroud.

DETAILED DESCRIPTION

Referring to FIGS. **1** and **2**, a preferred embodiment of the invention employing a shroud between a dish-shaped reflector and randome is shown generally at **12.** The assembly comprises a number of substantially identical segments **14, 16, 18** and **20,** each of which is an integrally formed rigid structure.

According to one form of fabrication each segment is formed by a thermosetting resin saturated fiberglas fabric draped over a rigid form and heated to set the resin, thereby forming a rigid structure. The resin may be of the polyester type or the epoxy type, or it may consist of any other material that is substantially transparent to microwave radiation. Alternatively, the structure may be vacuum formed or formed by other techniques familiar to those in the art.

Referring to FIG. **2**, the detailed structure of the segment **20** is described in furthe detail, the other segments being substantially identical thereto. As shown, the segment **20** is a quarter segment but it will be obvious that the angle which it subtends may be greater or less than 90°. The total of all of the angles subtended by the segments equals 360° in the embodiment shown, although it will be evident from this description that the teachings of this invention are fully applicable to antennas utilizing reflectors that are only fragmental or partial paraboloids of revolution.

The segment **20** includes a reflector portion **22,** a shroud portion **24** and a radome portion **26,** the portions **22** and **26** having parabolic shaped interior surfaces **28** and **30,** respectively. The foci of the surfaces **28** and **30** are coincident at a point P. The shroud portion **24** is preferably of generally cylindrical shape having a diameter equal to or slightly greater than that of the reflector and radome portions at the respective circular lines of intersection therewith. An integral flange **32** extends around the segment along the lines abutting contiguous segments, and holes **34** are formed in the flange for receiving bolts **36** or other equivalent fasteners. Suitable brackets **38** or other hardware for mounting the antenna may be bolted or otherwise secured to the flanges of the segments or to other convenient parts of the assembly.

A microwave antenna feed, designated generally at **40,** is mounted in position to direct energy against the parabolic surface **28** of the reflector from the point P. To this end, any known type of feed, microwave emitter or radiator may be employed and positioned so that the apparent point source of radiation is coincident with the point P. In the illustrated embodiment a microwave conductor **42** is led in through a flanged sleeve **44** and terminates in a horn **46.** A support **48** is preferably attached to the conductor **42** and secured to a sleeve **50** similar in configuration to the sleeve **44.** If desired, other alternative forms of feed may be employed and may be supported at positions other than those defined by the axial sleeves **44** and **50.**

The surface **28** of the reflector is made electrically conductive by any one of a number of known techniques such as metallic spraying or securing thereto a screen, metallic foil or sheet metal. Similarly, an interior surface **52** of the shroud portion **24** is made electrically conductive, the conducting surfaces **28** and **52** being electrically continuous and electrically interconnected along the circular line **54** defined by the peripheral rim of the reflector portion **22.** The surface **52** is preferably undulating so as to cause diffusion of stray reflections impinging thereon. In the illustrated embodiment the shroud portion **24** is fabricated over a corrugated form, but other alternative types of nobby surfaces may be substituted, if desired. Therefore, as used herein the word "undulating" is intended to include any irregular, corrugated, nobby or otherwise shaped or deformed surface having an equivalent property. The corrugated shape has the further advantage of imparting mechanical stiffness to the structure, thereby permitting it to be formed of lighter materials without loss of dimensional integrity. In any case, there is no gap at the peripheral edge of the reflector portion **22** and shroud **24** where energy might leak and cause diffraction or back radiation.

As shown in FIG. **3,** the segments **14, 16, 18** and **20** may be conveniently nested, thereby materially reducing the volume of the components for purpose of storage and shipment. It is also apparent that, since the reflector, shroud and radome portions of each segment are formed as parts of an integral structure under factory conditions, it is assured that the foci of the reflector and radome portions are precisely coincident.

The foregoing structural features and advantages readily permit the construction of large antennas having high gain and performance. This can be attributed to the novel segmental construction which affords structural strength, dimensional integrity and precision, and provision for reducing the shipping volume of the antenna.

Further features of the above-described antenna arising from from the confocal geometry may be understood by reference to the schematic diagram of FIG. **4,** wherein the parabolic reflector surface **28** is shown as having a focal length f_1 and the parabolic radome surface **30** is shown as having a focal length f_2. The overall diameter has the value D, and the axial length of the shroud surface **52** is L. The point P lies at the intersection of the common axis **58** of the two parabolic surfaces and a common focal plane **60** normal to this axis.

Typically, the value of D is determined preliminarily according to the gain required of the antenna. The value f_1 is also given and it is usually in the vicinity of four-tenths of the value D, although the invention is in no way limited to this precise relationship. With given values of D and f_1, it will be apparent that the depth d_1 of the reflector surface **28** is defined by the parabolic equation

$$(D/2)^2 = 4f_1d_1. \qquad (1)$$

The length L of the shroud may then be determined by the expression

$$L = f_1 + H - d_1, \qquad (2)$$

where the value H is arbitrarily assigned on the basis of tests and is sufficient in magnitude to prevent appreciable stray radiation by the feed from leaking around the shroud.

The focal length f_2 and the depth d_2 of the radome are then readily calculated, as follows. Since

$$(D^2/2) = 4f_2d_2 \qquad (3)$$

and $d_2 = f_2 - H$, the following quadratic equation may be derived:

$$f_2^2 - Hf_2 - (D^2/16) = 0, \qquad (4)$$

for which the quadratic formula provides the solution

$$f_2 = \frac{H + \sqrt{H^2 + \frac{D^2}{4}}}{2}. \qquad (5)$$

Once the value f_2 is determined the value d_2 is readily found from equation (3).

In some applications a shroud is not required, in which case the structure defined with reference to FIGS. **1** to **3** may be simplified as illustrated in the schematic diagram of FIG. **5.** In this figure, since

$$d_1 + d_2 = f_2 + f_2, \qquad (6)$$

and since equations (1) and (3) above also hold for this figure, it may be shown that

$$d_2 = f_1 \text{ and } f_2 = d_1. \qquad (7)$$

By reason of the foregoing relationships, it will be apparent that any energy from the focus P that is reflected from the parabolic surface **28** will impinge on the surface **30** in a direction parallel to the axis **58** and that any energy reflected from the latter surface will be directed through the focus P, and that this energy will again impinge upon the surface **28** for a second reflection from the latter in the same direction as the first reflection. In fact, this relationship holds for any number of reflections and for any frequency of transmission.

Further, it may be shown that the total path length from the focus P to the reflector surface **28,** thence to the radome surface **30** and back to the point P, is given by the expression

$$S = 2(f_1 + f_2), \qquad (8)$$

and therefore reflection from all portions of the radome surface return to the point P in phase with each other and with the original signal. This results from a fundamental property of a parabola, namely, that the path length of a beam from the focus to any point on the curve and thence by reflection to the focal plane, is always equal to twice the focal length. This property maintains the coherency of the signal regardless of frequency, and radome-equipped antennas will have this property only if configured and spatially related in accordance with the foregoing equations and diagrams.

Also, in considering these equations and diagrams, it will be recognized that, although they are described above with reference to paraboloids of revolution, the confocal relationships can be realized in alternative practical configurations, for example parabolic cylinders. Thus the reflector may be illuminated by a feed radiating from a line or other locus rather than from a point, and the reflector and radome may have parabolic cross sections which are uniform along all sections transverse to such radiating line or locus, and FIGS. 4 and 5 are illustrative of such cross sections. For this reason the word "parabolic" as used herein refers only to a cross sectional configuration of the parts and does not necessarily imply any limitations in the dimension normal to such cross section.

I claim:

1. A microwave antenna having, in combination,

a reflector having a parabolic inner electrically conductive surface,

a microwave feed in position to radiate energy to and from the focus of said electrically conductive surface,

and a radome having a parabolic inner electrically nonconductive surface connected with the reflector in a position with its focus coincident with that of said electrically conductive surface.

2. An antenna according to claim **1**, in which the reflector and radome are dish shaped and connected by means of their peripheral rims.

3. An antenna according to claim **2**, including a shroud spacing and interconnecting the reflector and radome at their peripheral rims.

4. An antenna according to claim **2**, in which said coincident foci are spaced from the plane defined by the rim of the reflector and on the side of said plane opposite to the reflector.

5. An antenna according to claim **2**, in which said coincident foci are located in the plane defined by the rim of the reflector.

6. An antenna according to claim **3**, in which said coincident foci are spaced from the plane defined by the rim of the reflector and on the side or said plane opposite to the reflector.

7. A microwave antenna having, in combination,

a plurality of segments, each segment including a fragmental parabolic reflector portion and a fragmental radome portion, said portions of each segment being integrally formed, said segments having provision for interconnection at their periphery to form an enclosure.

8. An antenna according to claim **7**, in which the radome portion is of fragmental parabolic shape.

9. An antenna according to claim **8**, in which the foci of the reflector and radome portions are coincident.

10. An antenna according to claim **7**, in which each segment includes a fragmental shroud portion integrally formed with and interconnecting the reflector and radome portions.

11. An antenna according to claim **10**, which is electrically continuous at the line of intersection between the shroud and the parabolic periphery of the reflector portion.

12. An antenna according to claim **11**, in which the surfaces of the reflector and shroud portions have electrically conducting surfaces.

13. An antenna according to claim **10**, in which the shroud portion has an undulating surface.

14. An antenna according to claim **9**, including a feed supported for radiation reciprocally in relation to a point located at said coincident foci.

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