April 13, 1965 R. F. H. YANG 3,178,713

PARABOLIC ANTENNA FORMED OF CURVED SPACED RODS

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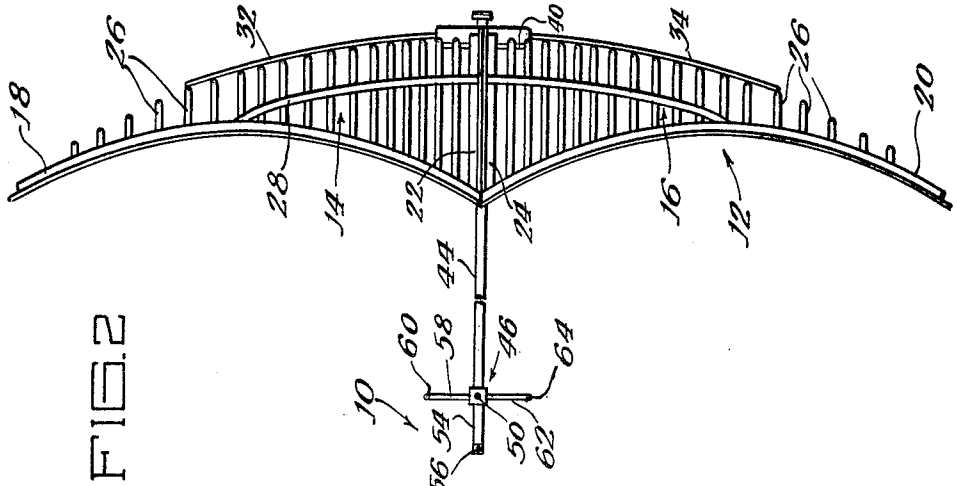


FIG. 2

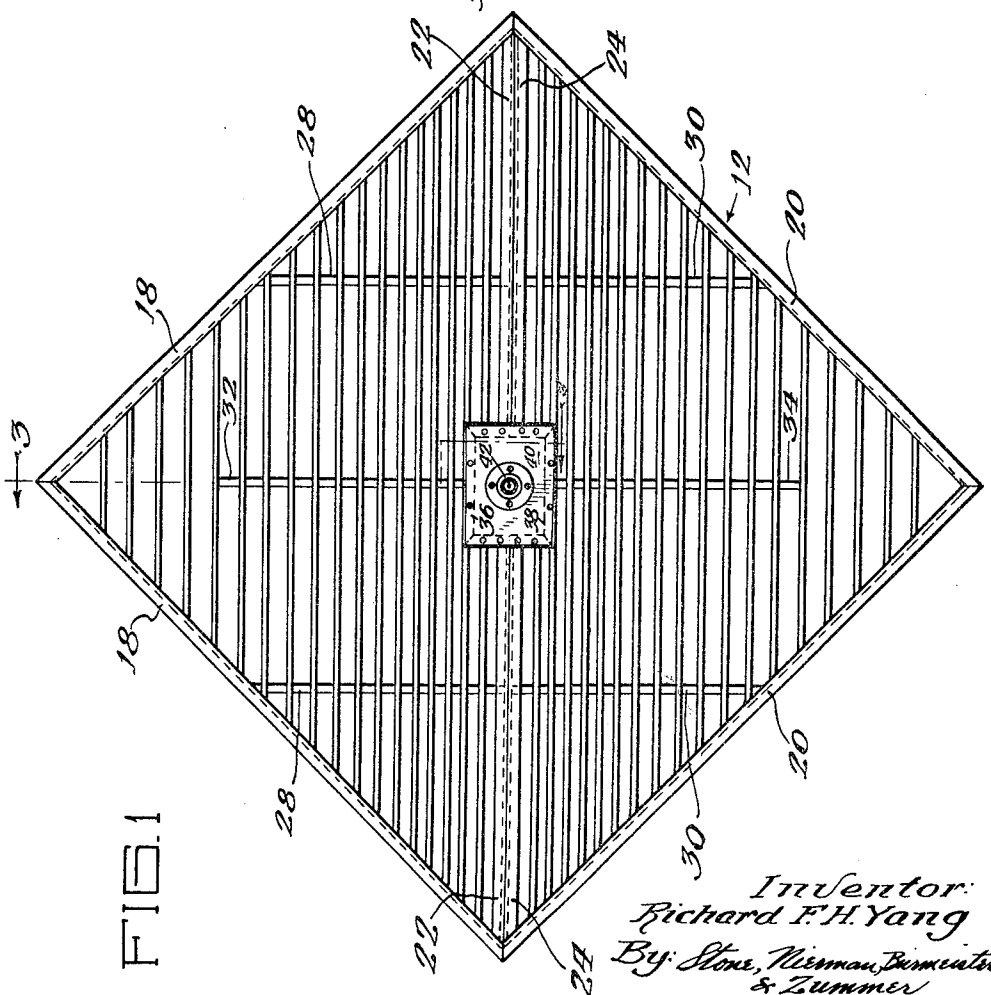


FIG. 1

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FIG. 3

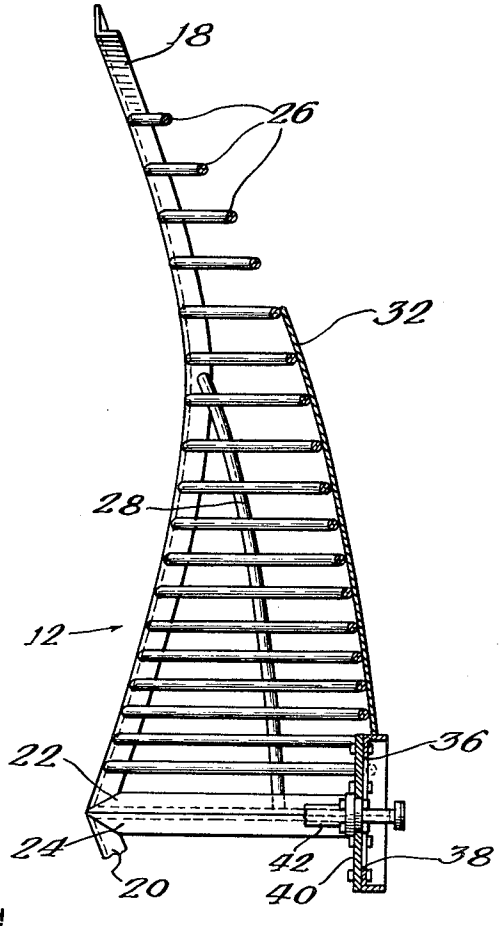
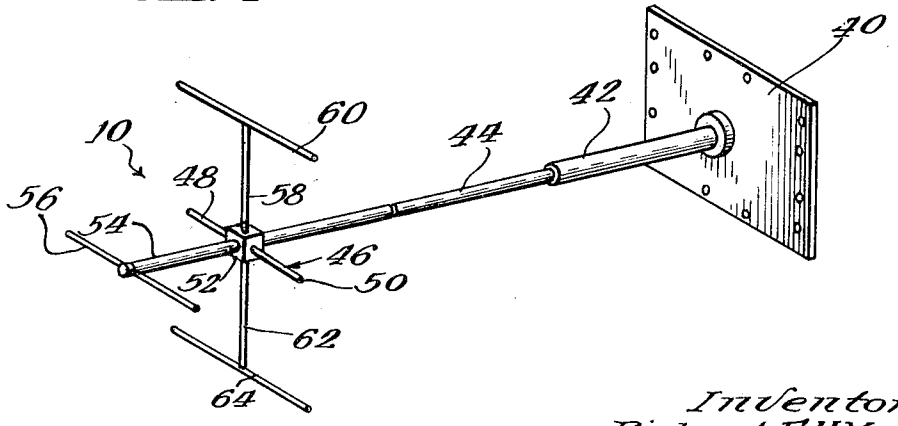


FIG. 4



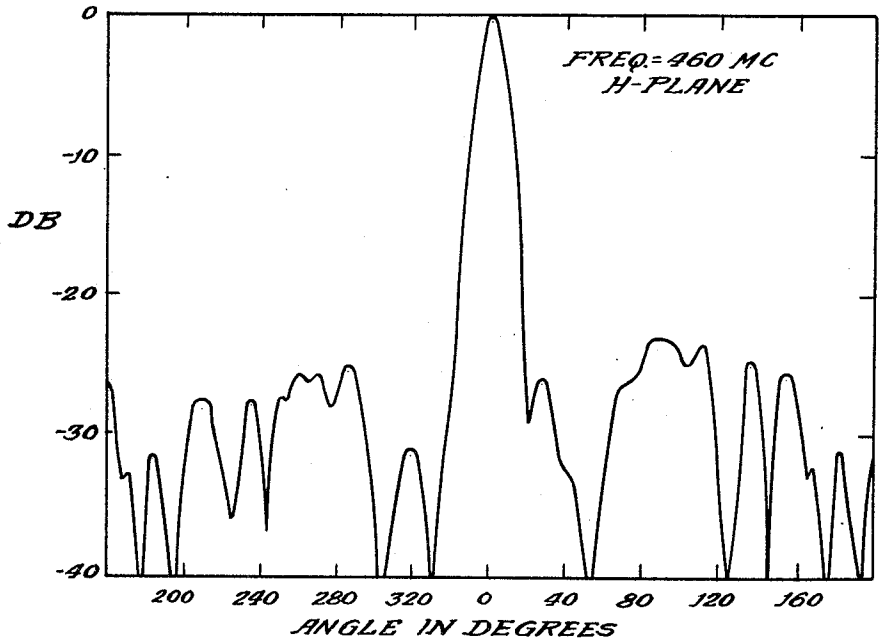
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FIG. 5



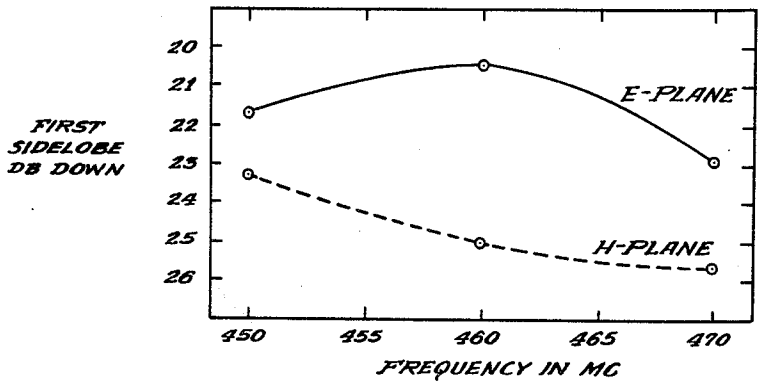


FIG. 6

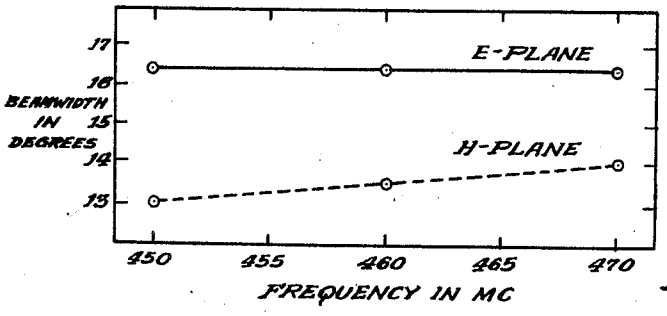


FIG. 7

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PARABOLIC ANTENNA FORMED OF CURVED SPACED RODS

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5 Claims. (Cl. 343—840)

This invention relates to reflector-type antennas, particularly to parabolic antennas.

The invention is primarily concerned with the reduction of undesired sidelobes in the radiation patterns of parabolic antennas designed to have similar patterns when employed in vertically polarized and horizontally polarized transmission. (It will, of course, be understood that the principles of construction herein discussed are applicable to receiving antennas, so that terms such as "transmission" are not limitative in this respect.) However, in addition to the features of construction which produce this result, the invention provides further features which may be more generally applied.

The type of parabolic antenna in most general use employs a reflector of round aperture, i.e., a parabolic surface subtending a circle in the direction of focus. From mere gross or elementary optical principles, the radiation pattern of such an antenna appears to be fully concentrated in the desired direction. In fact, however, as is well known, actual measured radiation patterns have numerous sidelobes at angles to the desired direction. These sidelobes have a number of explanations, both from the practical and theoretical standpoints. From the practical standpoint, deviation from the performance predicted from elementary optical theory is due to a number of factors which vary from the ideal conditions assumed by such elementary theory. In the first place, of course, the feed is not the theoretical point source which elementary theory assumes. Nor is it possible to achieve the ideal conditions of perfectly even distribution of "illumination" of the reflector. The pattern is further affected by such factors as the presence of the earth and a variety of similar phenomena. Additionally, the dimensions of practical reflectors are far from infinite as compared with the wavelength, so that considerations of phase of elementary components of the signal which contribute to its strength at any given point become of great importance.

A large amount of theoretical work has been done on the matter of the operation of parabolic and other types of reflector antennas, taking into account at least the major ones of these variables. In recent years, it has been demonstrated that substantial improvement can be made in sidelobe reduction by suitable shaping of the reflector of a parabolic antenna. For example, there appears in the literature the so-called "cosine-squared" reflector aperture, which is shown both theoretically and experimentally to give substantial improvement. There has also been described (Brueckmann, Proceedings of the Institute of Radio Engineers, Volume 46, Page 1510) a form of rhombic aperture in which the lower corner is flattened to become a part of the ground plane.

For a number of reasons, the use of specially shaped apertures for sidelobe reduction has heretofore not been considered practical in most commercial applications, particularly for VHF and UHF transmission. At these high frequencies, the elevation required for efficient operation imposes a requirement of low wind loading which is best met by employing a reflector of the type constructed with parallel rods. Such a reflector operates properly only where the rods are in the direction of polarization produced by the feed for the reflector. In order to

minimize interference and cross-talk between communication systems in the same general vicinity, it is customary to use different directions of polarization in such systems, in addition to such precautions as may be taken to cut down sidelobes in the patterns of the antennas employed. It is thus desirable that an antenna for commercial use be capable of the desired characteristics of operation with either vertical or horizontal polarization. Thus, reflectors of circular aperture continue in common use for such purposes, since the rod-type reflectors heretofore proposed as improvements on the circular aperture are not satisfactory for operation in both types of polarization, the difference in aperture aspect upon the 90° rotation of the entire antenna which is necessary for polarization change destroying the desired sidelobe pattern when the reflector is designed for either of the two possible polarizations.

The present invention provides a parabolic antenna which better meets the requirements for commercial use at VHF and UHF than those heretofore proposed or used. With the present construction, the sidelobes are greatly reduced as compared with a reflector antenna of circular aperture, without loss of substantial uniformity of the sidelobe pattern when the antenna is oriented for vertical or horizontal polarization. In addition, the efficiency in confinement of radiation to the desired direction is aided by substantial reduction of "spill-over" (radiation from the feed which does not strike the reflector) and also by reduction of the back radiation (primarily leakage through the grid forming the surface of the reflector) with a minimum of addition to the wind loading of the reflector and to the cost of the antenna.

The features of construction by which these advantages are obtained are incorporated in the embodiment of the invention hereinafter to be described. It has been found through theory, and verified by experiment, that a square aperture, i.e., a paraboloidal surface subtending a square in the direction of focus with a feed polarized in the direction of a diagonal of the square, will produce a much lower first sidelobe amplitude in the horizontal plane than a circular aperture, irrespective of whether vertical or horizontal polarization is used, the difference in patterns obtained in the two polarizations being relatively minor as compared with the difference obtained with aperture shapes heretofore suggested for sidelobe reduction. This finding has been employed to produce a parabolic antenna which may be readily oriented for either polarization in the same manner as a circular aperture antenna in which the reflector surface is formed of parallel conductors.

In the embodiment to be described, a dipole type of feed is employed. In addition to the reflector element or grounded rod usually employed with such a feed, spaced forwardly from the dipole, there are provided two additional reflector rods at the sides of the dipole, confining the sideward radiation from the dipole. As will hereinafter be pointed out, this geometry of the reflectors appears on first glance to be in the nature of a skeleton corner reflector, but is found to produce greatly superior results to those obtained by employing a larger number of rods to fill in the gaps in the "corner," while at the same time substantially reducing the cost and complexity as compared with a corner so constructed. An additional feature of construction of the embodiment to be described utilizes the recognition that the necessary spacing of the rods from which the reflector dish is constructed in order that the surface may act as a continuous conductor to any desired degree is not constant on all portions of the surface. The effective or apparent spacing at the edges of the dish is smaller than the actual physical spacing because of the difference in angle of incidence of the radiation from the feed, and this fact is utilized to reduce

the weight, wind loading, and cost of the antenna by increasing the spacing with distance from the center of the dish.

The embodiment of the invention to be described also includes further features of construction which are novel and contribute substantially to the provision of an overall construction of high performance, convenience of transportation and use, and relatively low cost. These additional features will best be understood from the description of a single embodiment, which has been selected for illustration in accordance with the patent laws, and is shown in the attached drawing, in which:

FIGURE 1 is a view in front elevation of a parabolic antenna embodying the various construction features of the invention;

FIGURE 2 is a view in side elevation of the antenna of FIGURE 1;

FIGURE 3 is a sectional view taken along the offset line 3—3 of FIGURE 1;

FIGURE 4 is a view in orthogonal perspective of the feed of the antenna;

FIGURE 5 is an experimentally obtained radiation pattern of the antenna illustrated;

FIGURE 6 is a plot of maximum sidelobe level of the antenna as a function of frequency; and

FIGURE 7 is a plot of half-power beamwidth as a function of frequency.

The illustrated embodiment of the invention has a feed generally designated at **10** and a reflector dish generally shown at **12**. The latter is composed of two triangular sections **14** and **16**. These are in the general form of isosceles right triangles (as viewed from the front) formed by pairs of perpendicular side frame members **18** and **20** and cross frame members **22** and **24** forming the hypotenuses. These frame members are of suitable angle material curved in such a manner as to appear as right triangles in front aspect. The reflecting surfaces or bodies of the segments **14** and **16** are formed of spaced parallel rods **26** bent in planes which are parallel with each other and with the cross frame members **22** and **24**, the bending of the triangular frames and the rods forming a reflecting surface in the general form of a paraboloid of revolution cut away to form a square aperture, i.e., subtending a square in the direction of focus. The spacing of the rods is relatively small as compared with the wavelength of the tuned frequency of the feed **10** at all points. However, in order to minimize both cost and wind resistance, the spacing is gradually increased with distance from the center-line of the reflector, i.e., from the joint between the cross frame members **22** and **24** of the triangular sections or segments. The inner or longer rods **26** are secured in relative position by pairs of tie rods **28** and **30** and a central strap **32** and **34**. The spacing of these tying members is large, so that the reflecting surface consists substantially entirely of the rods **26**.

The bases or cross members **22** and **24** of the triangular sections are formed with rectangular notches or offsets **36** and **38** with suitable framing members forming a mount for a feed support plate **40**, the innermost rods **26** having their central portions cut away for this purpose.

The plate **40** supports a mounting tube **42** which in turn supports a rigid coaxial line **44** on the end of which the radiating portion of the feed is mounted. The latter consists of a dipole **46**, consisting of dipole elements **48** and **50**, one being connected to the inner conductor of the coaxial line **44** and the other to the grounded outer conductor in conventional manner. A block **52** serving for the mounting of the dipole **46** is traversed by an aperture from which extends an extension **54** of the outer conductor of the coaxial line **44**. A reflector rod **56** is mounted on this extending end in conventional fashion. A conducting support rod **58** extends from the block **52** in one of the vertical (in the illustrated condition) directions, and a reflector rod **60** is mounted on the end of this support, parallel with the dipole **46**. A similar conducting

support **62** on the other side supports a reflector rod **64**. It will, of course, be understood that all of the elements of the feed visible in the drawing are conducting, all being grounded to the outer coaxial line conductor, except that the feed dipole element is brought out through the block **52** from its connection to the inner conductor by means of conventional insulators (not illustrated). Accordingly, all three of the rods **56**, **60** and **64** are grounded.

The three reflector rods are spaced from the radiating dipole **46** by a quarter wave length at the frequency of the dipole, and are somewhat longer than the half-wave dipole, as is conventional in any reflector rod element.

It will, of course, be understood that the illustrated antenna is designed to be employed with a suitable mount attached to the back for securing the antenna to a tower, building, or other elevated structure.

One commercial version of the antenna illustrated is designed for operation in the 460 megacycle band. This embodiment employs a square aperture of 12½ foot diagonal span giving an aperture area substantially the same as a circular reflector of 10 foot diameter. The focal length employed is 44 inches. Three-quarter-inch aluminum tubes are employed, being welded to the angle framework, also of aluminum. The spacing of the bars is tapered from 5 inches at the extreme H-plane tips of the triangular sections to 2½ inches at the center, corresponding respectively to 0.195 wave length and half of that value. It will, of course, be understood that the permissible degree of total spacing taper increases with aperture size and decreases with focal length for any given frequency. The 2 to 1 taper in spacing was experimentally found to give very satisfactorily low back radiation with the dimensions just discussed. For best utilization of this construction, the taper in spacing is preferably continuous, each successive rod outward from the center being increasingly spaced from its neighbor, thus obtaining the maximum effective simulation of a solid conductor with a minimum of added weight, expense, and wind-loading. Placing of the rods in parallel planes greatly simplifies assembly as compared with, for example, mounting the rods in planes converging on the feed, also offering the advantage that it is not necessary to use unnecessarily small spacings at the E-plane edges in order to obtain sufficiently small spacing at the center, as is required where the planes of the rods converge.

The employment of three reflector rods with the feed dipole was reached after substantial experimentation indicated the superiority of this arrangement over arrangements with further added reflector rods. For example, the "filling in" of the skeleton corner reflector with two or four more rods symmetrically placed was found to degrade, rather than aid, the performance of the antenna. It is believed that the superiority of the construction illustrated as regards performance is due to phase interferences of the additional reflectors with the phase phenomena introduced in the parabolic focusing action.

FIGURE 5 of the drawing shows the H-plane radiation pattern of the antenna described above, i.e., the pattern obtained at the median frequency with the antenna oriented for vertical polarization. It will be observed that the maximum (first) sidelobes are down almost 25 db from the beam maximum. This is approximately 5 db lower than the lobes obtained with a standard dipole (one reflector rod, rather than three) in a 10 foot round dish otherwise generally similar.

The sidelobe amplitude as a function of frequency over the band from 450 to 470 megacycles is shown in FIGURE 6 for both polarizations. It will be observed that the E-plane sidelobe attenuation is not as good as that obtained in the H-plane. Somewhat similar effects, i.e., differences in sidelobe amplitude in the two orientations, are obtained in any reflector antenna in which the directivity is not identical in both planes because of the presence of one or more reflectors on the feed which do not operate identically in both planes. This is particu-

larly true where the feed is not balanced. In the present instance, the H-plane superiority is somewhat increased by the fact that the reflectors employed on the feed substantially reduce spill-over only in the H-plane. Either of the characteristics shown in FIGURE 6 is, however, substantially better than the corresponding characteristics obtained with a standard antenna as described.

FIGURE 7 shows the half-power beamwidth of the antenna described above as a function of frequency. Here again, due to the difference in H-plane and E-plane directivity of the feed, the E-plane beamwidth is substantially constant, and the H-plane beamwidth, although considerably narrower, varies very slightly with frequency. Here again, the characteristics in both instances compare very favorably with those of a circular parabolic aperture with a single-reflector feed.

Measurements of the gain of the antenna demonstrate that despite the saving of weight and wind-loading and the improvement of sidelobe characteristics, as compared with a solid circular standard antenna of the same reflector area, there is no sacrifice of gain. Thus it will be seen that the slight back radiation observable at the extremes in FIGURE 5 represents energy which is extracted from sidelobes, rather than from the main beam, in comparing the performance of the illustrated antenna with that of a conventional solid dish. Obviously, the employment of the square aperture with reflector dish surfaces more closely approaching a solid surface, at some sacrifice of increase of wind resistance, etc., enables the present invention to be employed in structures which produce even higher gain.

Persons skilled in the art will readily recognize that although the novel combination of features described above as being incorporated in the illustrated embodiment is highly advantageous for the particular purpose for which the present device was intended, many of the features may be used individually or combined in structures far different in general appearance and detail than that herein illustrated. Further, many modifications may be made, some obvious and others apparent after study, which nevertheless embody the teachings of the invention; as one example, the square aperture may be replaced, for certain purposes, with an aperture of some other non-circular shape which has equal diagonals respectively parallel and perpendicular to the direction of polarization and possesses mirror symmetry with respect to both diagonals. Accordingly, the protection to be afforded the invention should not be limited by the particular embodiment herein described, but should extend to all structures described in any one or more of the annexed claims, and to equivalents thereof.

What is claimed is:

1. In a parabolic antenna, a reflector dish comprising a substantially square frame and spaced parallel rods extending in the diagonal direction between pairs of adjacent sides of the frame, the spacing between adjacent rods increasing with distance from the center, the rods and the frame members being bent to form a paraboloidal segment subtending a square in the direction of focus, and a feed at the focus adapted to produce transmissions linearly polarized in the direction parallel with the rods.

2. In a parabolic antenna, a reflector dish comprising a pair of similar halves each having a frame in the general form of an isosceles triangle, and spaced parallel rods extending between the two equal sides of the frame parallel with the third side, the two halves being joined with said third sides in abutment, the rods and the frame members being bent to form a paraboloidal segment subtending a square in the direction of focus, and a feed at the focus adapted to produce transmissions linearly polarized in the direction parallel with the abutting third sides and with the rods.

3. In a parabolic antenna, a reflector dish comprising a pair of similar halves each having a frame in the general form of an isosceles triangle, and spaced parallel rods extending between the two equal sides of the frame parallel with the third side, the spacing between adjacent rods increasing with distance from said third side, the two halves being joined with said third sides in abutment, the rods and the frame members being bent to form a paraboloidal segment subtending a square in the direction of focus, and a feed at the focus adapted to produce transmissions linearly polarized in the direction parallel with the abutting third sides and with the rods.

4. A reflector dish for parabolic antennas comprising a substantially square frame, and spaced parallel rods extending in the diagonal direction between pairs of adjacent sides of the frame, the spacing between adjacent rods increasing with distance from the center, the rods and the frame members being bent to form a paraboloidal segment subtending a square in the direction of focus.

5. In an antenna comprising a generally paraboloidally curved reflector dish and a feed at the focus of the reflector dish adapted to produce linearly polarized transmissions, the improved construction wherein the reflector dish comprises a pair of similar halves each comprising a frame in the general form of an isosceles triangle, and spaced parallel rods etxending between the two equal sides of the frame parallel with the third side, the spacing between adjacent rods increasing with distance from said third side, the two halves being joined with said third sides in abutment, the rods and the frame member being curved to form a paraboloid segment subtending a square in the direction of focus, the feed comprising a dipole in the plane of the abutment of said third sides and three reflector rod elements parallel with the dipole and equally spaced therefrom in the direction away from the dish and in the respective opposite sidewise directions perpendicular to the dipole.

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