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PARABOLOIDAL ANTENNA WITH COMPENSATING ELEMENTS
TO REDUCE BACK RADIATION INTO FEED
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Fig. 2.

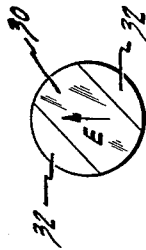
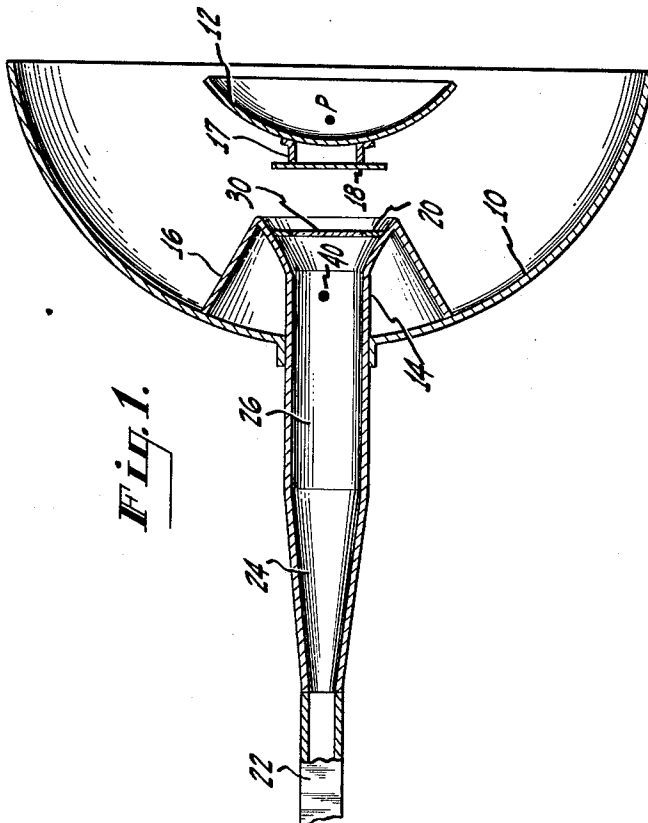


Fig. 1.



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PARABOLOIDAL ANTENNA WITH COMPENSATING ELEMENTS TO REDUCE BACK RADIATION INTO FEED

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The present invention comprises an improved broadband directive antenna characterized by high gain, low voltage standing wave ratio (VSWR) over a wide frequency bandwidth, and high ratio of forward power to backward scattered power (front-to-back radiation).

In brief, the antenna of the invention includes a deep parabolic reflector having a large aperture diameter/focal length ratio, a feed system in the form of a tapered horn with a conical cover, another reflector in the interior of the parabolic reflector and having an outer surface which faces the horn and reflects energy toward the parabolic reflector, and a specially designed impedance matching element mounted on the interior reflector and arranged to cancel energy tending to flow back into the feed horn. The cover for the horn is a frustum of a cone and is designed to extend back to and engage the interior surface of the parabolic reflector for preventing energy from entering the space behind the cover and setting up undesired resonances in this space.

Although parabolic reflector systems having interior reflectors have been proposed in the past, they suffer from several disadvantages, among which are: poor efficiency caused by waste of energy in the system, limited bandwidth, and poor impedance match over any appreciable range of operating frequencies. To overcome these disadvantages there has also been proposed a hog-horn antenna, but this particular antenna has relatively large dimensions and weight.

The antenna of the present invention is a high quality microwave antenna especially suitable for radio relay or radar applications. It overcomes the foregoing difficulties of the prior known antennas and achieves the best characteristics thereof while obtaining higher gain with a simpler construction.

A feature of the present invention is the specially designed impedance matching plate mounted on the interior reflector, which minimizes the amount of energy radiated back from this reflector into the horn. This matching plate, together with the conical cover, reduces to a minimum the reflected energy entering the horn. This desirable result minimizes echoes which are a source of distortion and which may otherwise occur in the antenna feeder due to energy reflected back into the horn. Because of the particular distribution of the energy across the antenna aperture, the gain is larger than that usually obtained from parabolic antennas of identical size, and its VSWR is 1.1 or better over a relative frequency range of $\pm 15\%$. The antenna of the invention operates at high efficiency over a bandwidth of 600 to 1000 megacycles, can accommodate a multiplicity of radio frequency signals for transmission or receiving purposes, and can handle polarized signals of two orthogonal polarizations (or circular polarization).

A detailed description of the invention follows, in conjunction with a drawing, wherein FIG. 1 shows an embodiment of the invention, and FIG. 2 shows the configuration of the iris which is used in the feed horn.

The antenna of the invention shown in the drawing comprises an extra deep parabolic reflector 10 with a large aperture diameter/focal length ratio, an interior or central reflector 12 which faces and reflects the energy toward parabolic reflector 10, a tapered inner contour

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exponentially shaped circular horn 14, a conical cover 16 in the form of a frustum of a cone which extends back to the interior surface of the reflector 10, a circular, metallic, flat surface impedance matching plate 18 mounted on a metallic spacer 17 for cancelling the energy tending to flow back into the horn 14 from reflector 12, and an iris 20 which provides an impedance match at the horn aperture for a desired polarization signal. The use of a flat plate 18 results in the sharpest minimum radiation in the direction of the feed horn 14, as compared to other shapes, and hence is considered the best shape of plate for well matched systems. Shapes other than circular for the impedance matching plate 18 have greater frequency sensitivity, and are also sensitive for the polarization of the reflected wave. The throat reflection of the horn 14 is made to be as small as possible, and the near field distribution of the horn is arranged to result in a proper field distribution on the interior reflector 12. The radiation center of the horn 14 is designated 40 and is a point source of spherical waves at the throat of the horn. The location of point source 40 is determined by proper selection of the aperture dimensions of the horn 14. The interior reflector 12 is positioned between the focal point P of the paraboloid 10 and the horn 14. Focal point P is located inside the parabolic reflector 10 and is a virtual point source of spherical waves behind reflector 12. Any wave radiated from point 40 appears to originate from virtual point source P. Where the focal point of the paraboloid 10 and the optimum focal point of the interior or central reflector are identical, there results a main beam which is practically identical in the E and H plane down to the -10 db point.

The widest diameter of the conical cover 16 is the same, or approximately so within 10%, as the diameter of the interior reflector 12 so that there are no multiple reflections between the parabolic reflector 10 and the interior reflector. The apex of conical cover 16 approximately coincides with the focus of the parabolic antenna 10. Cover 16 also eliminates the reflections from the parabolic reflector 10 toward the horn 14. The ideal shape of the interior reflector 12 is a hyperboloid. The shape of the interior reflector provides a special aperture distribution at the parabolic antenna which results in high forward gain and low back lobe radiation.

The energy reflected by impedance matching plate 18 toward the horn 14 is of such phase and magnitude as to cancel (it is equal and opposite to) any energy reflected by interior reflector 12 toward the horn which might tend to enter the horn, at a particular frequency. Judicious selection of the diameter of plate 18 and the distance of this plate from the interior reflector 12, arrived at by trial and error, provides optimum impedance match and maximum bandwidth. The distance of plate 18 from the reflector 12 is determined by the spacer 17 which should provide a metallic connection between the plate and the reflector 12.

One method of exciting or feeding the antenna, given by way of example, is shown as including a rectangular waveguide 22 propagating the TE_{10} mode, and a tapered transition 24 which transforms the TE_{10} mode into the TE_{11} mode of the circular waveguide 26, the latter being connected to the throat of the horn 14. An iris 20 at the mouth or aperture of the horn 14 serves to compensate for reflections or discontinuities at this location in the horn, to thereby minimize echoes in the feed system. The iris also provides an impedance match to signals which are polarized either horizontal or vertical. In practice, the shape of the iris is circular with chord-shaped projections 32 as indicated in FIG. 2, and is oriented such a way that its symmetry line inclines 45° with the polarization of the incoming wave. A very thin fiberglass or mica window 30 of first class purity and

0.006" thickness closes and seals the apertured end of horn 14.

Because there is no abrupt transition from the feed waveguide to horn 14 and because the waves reflected from the parabolic reflector 10 and the interior reflector 12 do not re-enter the horn 14, the antenna is capable of a broadband impedance match. Other methods of feed than that using the rectangular waveguide feeding the circular waveguide through a transition section may be employed.

Although supports for the central reflector 12 have not been shown in the interest of clarity of illustration, these supports may take the form of a plurality of spaced rods of insulating material or metal extending between the outer circular edge of the central reflector 12 and intermediate points on the parabolic reflector 10. The use of metallic support rods provides higher rigidity for the antenna as compared to insulation rods with only a negligible increase in the input reflection coefficient. The parabolic antenna of the invention may be mounted close to its supporting towers.

In an antenna of the invention constructed and successfully tested, the parabolic reflector 10 was a 10 ft. spun aluminum deep dish having a focal length (F) to diameter (D) ratio (F/D) equal to .2 with a circular waveguide input, as contrasted to the conventional shallower parabolic antenna having an F/D ratio of .3 to .4. The voltage standing wave ratio (VSWR) over a frequency range of 1700 to 2300 megacycles (mc.) was 1.1 maximum over a $\pm 15\%$ relative frequency band and 1.06 maximum within $\pm 9\%$ relative frequency band. The maximum of front to back radiation ratio for the main polarized component in the 150° - 210° angular range over the entire frequency range was from 52 to 58 db, a value which is high compared to that obtainable with shallower conventional parabolic antennas. The same ratio for the cross polarized component was approximately 3 db higher. The gain was better than 34 db corresponding to 64% efficiency as compared to an isotropic radiator having an omnidirectional radiation pattern. The beam width was 3° (degrees) to the 3 db points, or, stated another way, a 3 db loss is obtained for a deviation of $\pm 1.5^\circ$ from the direction of maximum radiation of the beam. The beam width was 15° to the 20 db points, in an experimental model of the invention; while wide angle radiation of $\pm 75^\circ$ (degrees) was for the whole antenna approximately 37 db below the radiation in the direction of the main beam.

The antenna of the invention is characterized not only by large bandwidth, high gain, and low input reflection coefficient, but also by the complete absence of pockets, wells and traps in which water and condensed moisture can collect when mounted normally for horizontal radiation reception. It is rugged, provides a small wind load, and can withstand windgusts of over 125 miles per hour with a $\frac{1}{2}$ inch coat of ice without structural damage. Further, the antenna is simple in design and permits relatively easy pressurization of the feed horn 14. The antenna of the invention can be utilized to transmit a wide band of microwaves at frequencies in the frequency region of 6000 megacycles. The operating bandwidth at 6000 megacycles may be 1000 megacycles, and cover a range of 5660 to 6660 megacycles. It can be used with either horizontal or vertical polarized signals. Where it is desired to use the antenna with two polarizations, then a dually polarized circular waveguide should replace the transition 24 and be directly connected to waveguide 26. The size and position of iris 20 is such that the symmetry line of the axis and the direction of electric field enclose 45° . This position makes possible the application of perpendicular polarizations. The antenna of the invention is therefore particularly useful for radio relaying purposes for transmitting and/or receiving a multiplicity of signals of different frequencies.

What is claimed is:

1. A broadband directive antenna comprising a main parabolic reflector, an outwardly flaring horn mounted on the axis of the paraboloidal surface of said reflector and extending into the interior of said reflector, said horn having a throat and a wider mouth with said mouth located in the interior of the main reflector, a metallic cover in the form of a frustum of a cone extending from the mouth of the horn back to the inner surface of the main reflector, another reflector substantially hyperboloidal in shape facing said horn mouth, said other reflector being appreciably smaller in size than the main parabolic reflector and having its widest dimension substantially equal to the widest dimension of said frustum, the dimensions of said horn and other reflector being such that there is a point source of spherical waves at the throat of the horn and a virtual point source of spherical waves behind the other reflector, and a compensating element mounted on the central part of said other reflector facing the mouth of the horn for reflecting back toward the horn waves which are equal in amplitude but opposite in phase to the waves which are reflected back toward the horn from said other reflector.

2. A broadband, high ratio of forward power to backward power antenna comprising a main parabolic reflector, an outwardly flaring horn mounted on the axis of the paraboloidal surface of said reflector and extending into the interior of said reflector, said horn having a throat and a wider mouth with said mouth located in the interior of the reflector, a feed for said horn comprising, in the order named, a rectangular waveguide propagating the TE_{10} mode, a transition which transforms the TE_{10} mode into the TE_{11} mode, and a circular wave guide coupled between said transition and the throat of the horn; a metallic cover in the form of a frustum of a cone extending from the mouth of the horn back to the inner surface of the main reflector with the axis of the conical surface of said cover coinciding with that of said paraboloidal surface, another reflector substantially hyperboloidal in shape facing said horn mouth, said other reflector being appreciably smaller in size than the main parabolic reflector and having its widest dimension substantially equal to the widest dimension of said frustum, the dimensions of said horn and other reflector being such that there is a point source of spherical waves at the throat of the horn and a virtual point source of spherical waves behind the other reflector, and a compensating element in the form of a circular plate mounted on and spaced from the central part of said other reflector facing the mouth of the horn for reflecting back toward the horn waves which are equal in amplitude but opposite in phase to the waves which are reflected back toward the horn from said other reflector.

3. A broadband, high ratio of forward power to backward power antenna comprising a main parabolic reflector, an outwardly flaring horn mounted on the axis of the paraboloidal surface of said reflector and extending into the interior of said reflector, said horn having a throat and a wider mouth with said mouth located in the interior of the reflector, a metallic cover in the form of a frustum of a cone extending from the mouth of the horn back to the inner surface of the main reflector, another reflector substantially hyperboloidal in shape facing said horn mouth, said other reflector being appreciably smaller in size than the main parabolic reflector having its widest dimension substantially equal to the widest dimension of said frustum, the ratio of the focal length to the diameter of said antenna being approximately .2, the dimensions of said horn and other reflector being such that there is a point source of spherical waves at the throat of the horn and a virtual point source of spherical waves behind the other reflector, and a flat metallic plate mounted on the central part of said other reflector facing the mouth of the horn for reflecting back toward the horn waves which are equal in amplitude but opposite in phase to the waves

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which are reflected back toward the horn from said other reflector.

4. A broadband directive antenna comprising a main parabolic reflector, an outwardly flaring horn-like wave energy transducer mounted on the axis of the paraboloidal surface of said reflector and extending into the interior of said reflector, said horn-like transducer having a throat and a wider mouth with said mouth located in the interior of the reflector, a metallic cover in the form of a frustum of a cone extending from the mouth of the horn back to the inner surface of the main reflector, a reflector substantially hyperboloidal in shape positioned interior of said main reflector with said interior reflector having its convex face facing said horn mouth, said interior reflector being appreciably smaller in size than the main parabolic reflector and having its widest dimension substantially equal to the widest dimension of said frustum, the dimensions of said horn and interior reflector being such that there is a point source of waves substantially at the throat of the horn and a virtual point source of spherical waves behind the interior reflector, and a compensating element mounted on the central part of said interior reflector facing the mouth of the horn for reflecting back toward the horn waves which are equal in amplitude but opposite in phase to the waves which are reflected back toward the horn from said interior reflector.

5. A broadband directive antenna comprising a main parabolic reflector, an outwardly flaring horn mounted on the axis of the paraboloidal surface of said reflector and extending into the interior of said reflector, said horn having a throat and a wider mouth with said mouth located in the interior of the reflector, means for coupling wave energy translating means to said horn, a metallic cover in the form of a frustum of a cone extending from the mouth of the horn back to the inner surface of the main reflector, the apex of said cover approximately coinciding

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with the focus of the parabolic reflector, a reflector substantially hyperboloidal in shape positioned interior of said main reflector with said interior reflector having its convex face facing said horn mouth, said interior reflector being appreciably smaller in size than the main parabolic reflector and having its widest dimension substantially equal to the widest dimension of said frustum, the dimensions of said horn and interior reflector being such that there is a point source of spherical waves at the throat of the horn and a virtual point source of spherical waves behind the interior reflector, and a compensating element in the form of a circular plate mounted on and spaced from the central part of said interior reflector facing the mouth of the horn for reflecting back toward the horn waves which are equal in amplitude but opposite in phase to the waves which are reflected back toward the horn from said interior reflector.

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