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[54] SHAPED-BEAM ANTENNA FOR EARTH COVERAGE FROM A STABILIZED SATELLITE

9 Claims, 6 Drawing Figs.

[52] **U.S. Cl.** **343/778,** 343/786, 343/854
[51] **Int. Cl.** **H01q 13/00**
[50] **Field of Search** 343/776–779, 853, 854, 786

[56] **References Cited**

UNITED STATES PATENTS

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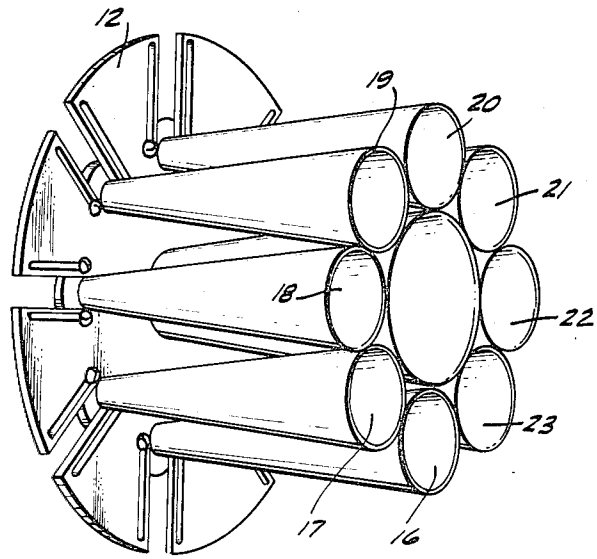
ABSTRACT: The apparatus of the present invention provides an antenna having a beam shaped for optimum earth coverage from a synchronous satellite. Due to the difference in range and atmospheric attenuation from a synchronous satellite to various points on earth, a conventional beam with maximum gain toward the center of the earth, is inefficient because it has the highest gain where the least gain is required. Since the paths tangential to the earth are longest and since they traverse through more atmosphere, the gain of the disclosed antenna is highest in this region and decreases to a minimum for the path normal to the earth. In addition, the beam pattern of the antenna has "flat portions" at the edge to allow for stabilization errors of the satellite whereby equal effective signal is provided over the entire portion of the earth covered by the antenna beam. The antenna generates a beam pattern that is rotationally symmetrical and has the capability of dual orthogonal polarization.



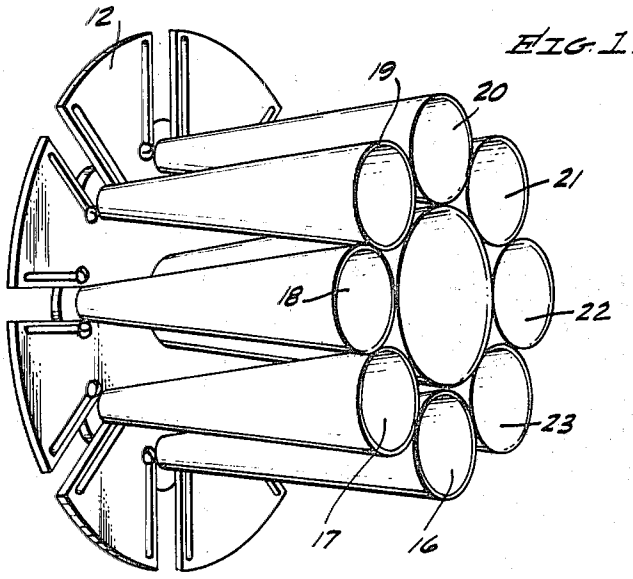


FIG. 1.

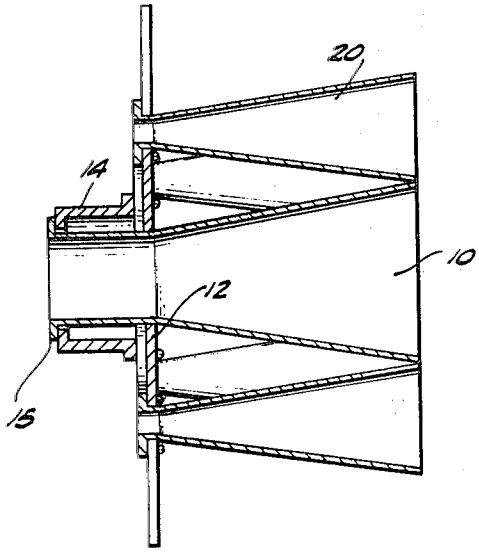


FIG. 2.

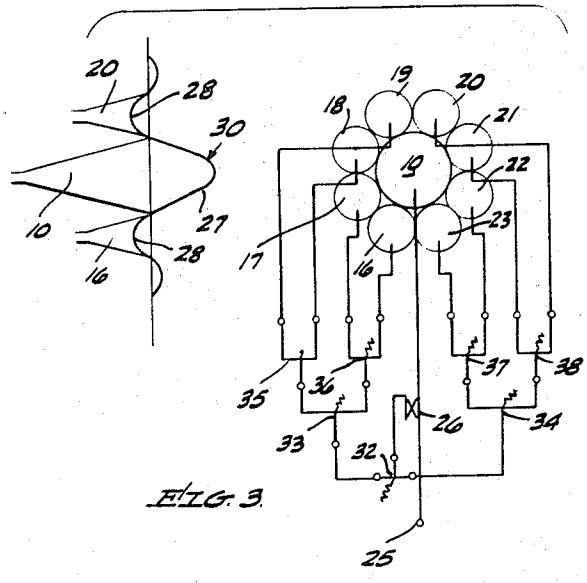


FIG. 3.

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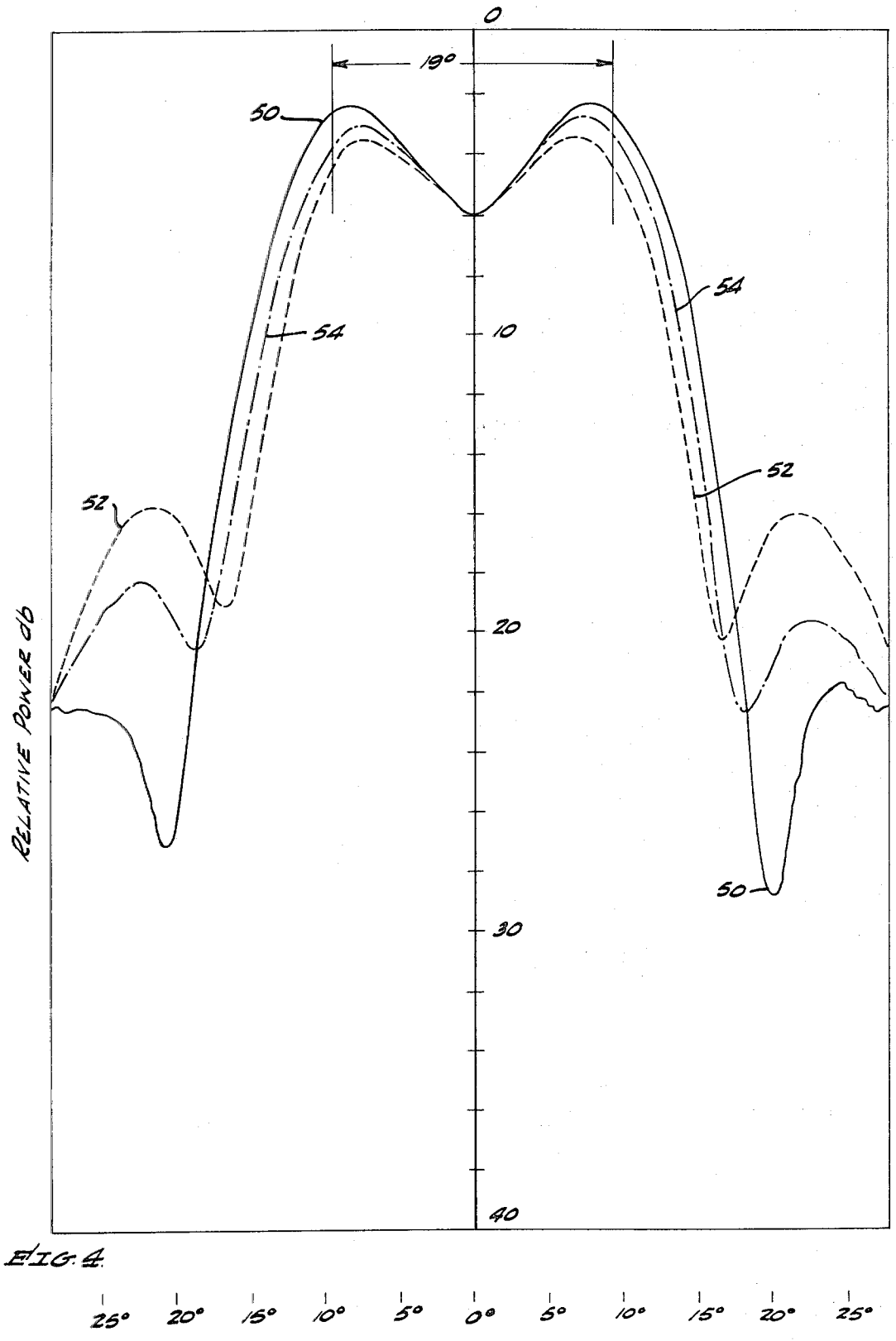
0
19°
50
54
54
52
52
50
10
20
30
40
RELATIVE POWER db
25° 20° 15° 10° 5° 0° 5° 10° 15° 20° 25°

FIG. 4.

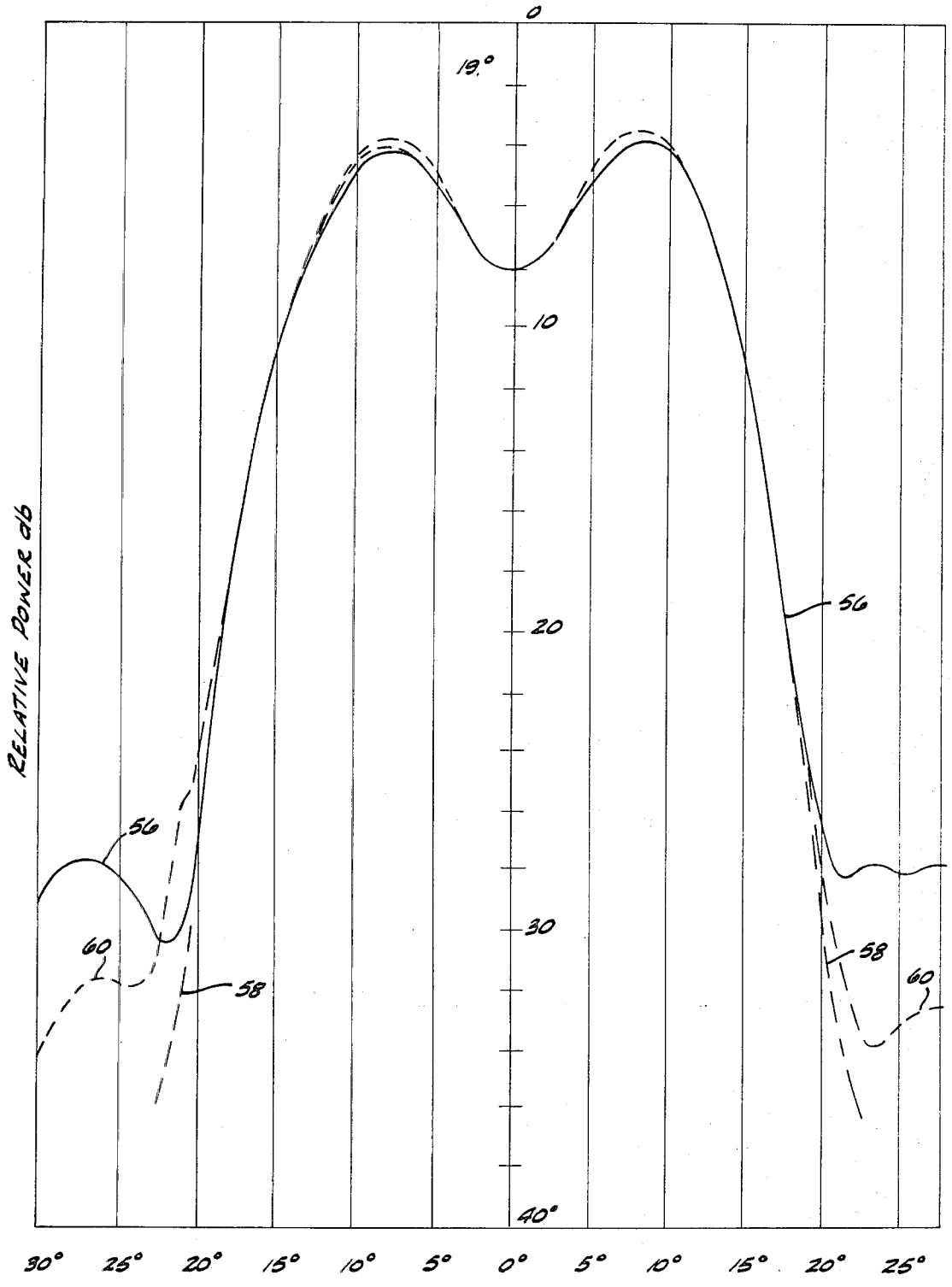
0
19.°
10
20
30
40°
RELATIVE POWER dB
56
56
60
58
58
60
30° 25° 20° 15° 10° 5° 0° 5° 10° 15° 20° 25°

FIG. 5.

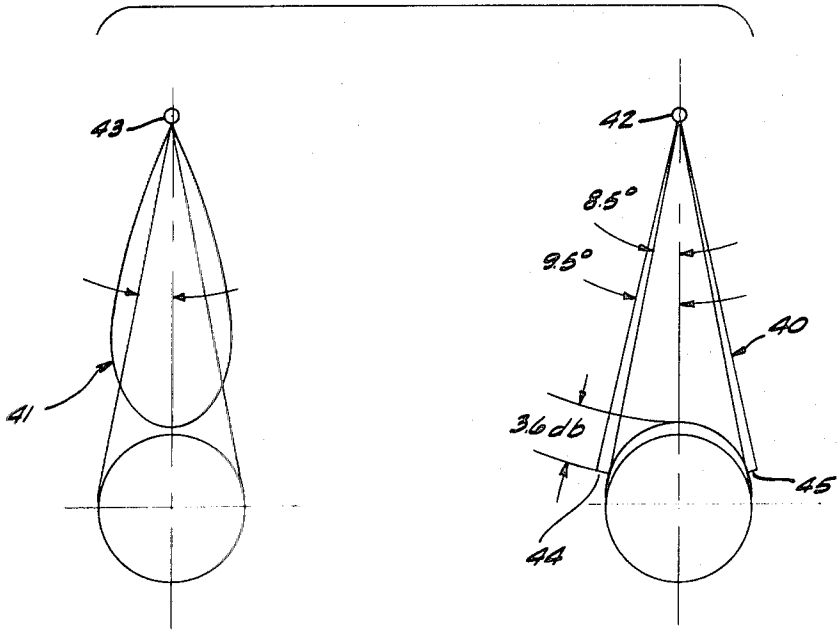

FIG. 6

SHAPED-BEAM ANTENNA FOR EARTH COVERAGE FROM A STABILIZED SATELLITE

BACKGROUND OF THE INVENTION

Contemporary antennas are simple or multimode horns and planar arrays of nominally half-wave elements spaced of the order of half to three-quarters of a wavelength. Simple or multimode horns do not give the proper shaping or are of extremely narrow bandwidth. An array, on the other hand, is extremely complex because of the large number of elements, is quite narrow band and is quite lossy because of complex feed network. Further, if polarization diversity is desired, the complexity is more than doubled.

SUMMARY OF THE INVENTION

It is well known that a Lambda function, $J_1(u)/u$, aperture distribution will give a rotationally symmetrical sector-shaped pattern exactly but would require an infinite aperture. In accordance with the present invention, this aperture distribution is approximated by a horn array wherein a larger center horn provides a distribution approximating the "main lobe" of the $J_1(u)/Au$ function while a ring of smaller horns 180° out of phase with the center horn approximates the distribution of the "first minor lobe" of the $J_1(u)/u$ function. The resulting horn array generates a concave shaped beam with almost perfect rotational symmetry and with minimum absolute gain greater than 18 db. 9.5° from center. When used on a stabilized satellite at synchronous altitude, 9.5° from center is at the earth's edge where one usually experiences the weakest signal. In addition to its use on satellites, the array of the present invention is also useful as the feed for a Cassegrain antenna.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates the nine-horn array of the invention, in perspective, without feed system;

FIG. **2** shows a cross section of the nine-horn array of FIG. **1**;

FIG. **3** shows a schematic diagram of a feed system for the nine-horn array of FIG. **1**;

FIG. **4** illustrates measured patterns of the nine-horn array of FIG. **1** without multimoding;

FIG. **5** illustrates measured patterns of the nine-horn array of FIG. **1** with center horn multimoded; and

FIG. **6** shows the ideal pattern for earth coverage.

DESCRIPTION

Referring now to FIGS. **1** and **2** of the drawings, the array of the present invention includes a large conical center horn **10** which is mounted to a disk **12** by means of a standoff support **14** attached to a flange **15** at the neck portion thereof. In accordance with the invention, an integral number of smaller conical horns **16–23** are disposed in alignment with and at equal intervals about the large conical center horn **10**. Although a number of horns equal to an exponential of the base two can be used, i.e., 2, 4, 8, 16 . . . , it has been found that the use of the eight conical horns **16–23** is advantageous from the standpoint of relative aperture area and simplicity of the driving apparatus. In order for the smaller conical horns **16–23** to surround the center horn **10** without leaving a gap, the diameter of the respective apertures thereof are made equal to 0.618 times the diameter of the aperture of the center horn **10**. Under these circumstances, the ratio of the area of the apertures of the conical horns **16–23** to the area of the aperture of the center horn 10 is 3. In addition, the flare angle of the center horn **10** and peripheral horns **16–23** control the phase front over the respective horn aperture. Larger flare angles produce more convex phase fronts and smaller flare angles less convex phase fronts. In this respect, the peripheral horns **16–23** can be "tilted" in with respect to the center horn **10** to achieve additional control of the phase over the entire aperture of the array. The disk **12** includes eight equally spaced radial slots adapted to accommodate the neck portions of the conical horns **16–23** thereby enabling the respective flanges thereof to be attached thereto. The center horn **10** may be "multimoded" in accordance with known techniques or as described in copending application for patent titled "-Broadband Multimode Horn Antenna" by James S. Ajioka, Ser. No. 771,178 filed Oct. 28, 1968 and assigned to the same patentee as is the present case. The specification of this patent is incorporated herein by reference.

Referring to FIG. **3** there is shown a schematic diagram of an apparatus for feeding the nine-horn array of FIG. **1**. As previously explained, the nine-horn array of the present invention approximates the "main lobe" **27** and "first minor lobe" **28** of a Lambda function $J_1(u)/u$ as indicated by the characteristic **30**, FIG. **3**. To achieve this, an input **25** passes through a power divider **26** and connects to the input flange **15** of the center horn **10**. The antenna pattern is "shaped" by the division of power between the center horn **10** and the surrounding smaller horns **16–23**. To achieve the division to approximate the characteristic **30**, the power divider **26** splits the power in a manner to direct 95 percent of the input power to the center horn **10**. The remaining output from power divider **26** is connected to the shunt arm of a magic tee **32**, the series arm of which is terminated. Output arms from the magic tee **32** are, in turn, connected to shunt arms of magic tees **33, 34**, the series arms of which are again terminated. The output arms of magic tees **33, 34** are then connected to the shunt input arms of magic tees **35, 36, 37, 38**, the series arms of which are terminated. Finally, the output arms of the magic tees **35, 36, 37, 38** are connected to the input flanges of the smaller conical horns **16–23**. The inputs of the conical horns **16–23** are oriented in a manner such that the polarity of the signal appearing at the respective apertures thereof are 180° out of phase from the signal appearing at the aperture of the large conical horn **10**. The 180° phase difference is employed because of the opposite polarity of the "first minor lobes" **28** relative to the "main lobe" **29** of the characteristic **30**. All of the inputs to the conical horn **10** and to the conical horns **16–23** are designed to launch a dominant TE_{11} mode which may be "multimoded" in the case of horn **10**. In the event that dual orthogonal polarization is desired, an orthogonal mode transducer (not shown) is interposed between each horn **10, 16–23** and the feed network of FIG. **3** and a similar network connected from the orthogonal mode transducers used for the orthogonal mode. Also it is understood that the terminations can be removed from any or all of the magic tees **32–38** for the purpose of providing antenna-pointing error correction information commonly known as monopulse operation. In the case of operation from a stabilized satellite, error correction is not required as there is no movement between the transmitter and receiver other than minor variations resulting from the stabilization.

Referring to FIG. **6** there is shown an ideal pattern **40** for earth coverage versus a conventional pattern **41** for operation from synchronized satellites **42, 43**, respectively. The ideal pattern **40** has shoulders **44, 45** which are 3.6 db. up from the center beam intensity whereby maximum signal is directed toward the edge of the earth as seen from the satellite **42** thereby providing a substantially uniform signal over the portion of the earth's surface covered. The shoulders **44, 45** of pattern **40** are of the order of one degree in width to allow for minor errors in the orientation of the satellite **42**. As contrasted with the ideal pattern **40**, the conventional pattern **41** is the weakest at the edge of the earth where maximum signal is needed. Also, a substantial portion of the pattern **41** is wasted as the energy therein never falls on the earth.

In the operation of the nine-horn array of FIG. **1**, the ideal pattern **40** is approximated by using a flare angle of the order of 10° for the center horn **10** and for the peripheral horns **17–23** and by adjusting the power divider **26** to deliver 95 percent of the input power to the center horn **10** whereby the remaining 5 percent of the input power is divided between the surrounding horns **16–23** by the magic tees **32–38**. A domi-

nant TE_{11} mode is launched in each of the horns **16–23** and in the center horn **10**. Under these circumstances, the nine-horn array of FIG. **1** generates a beam having the H-plane pattern **50**, the E-plane pattern **52** and the diagonal plane pattern **54** shown in FIG. 4. As shown in the drawing, the patterns **50**, **52**, **54**, in addition to having rotational symmetry and polarization purity, have a shoulder-to-shoulder width of 19° which approximates that of the ideal pattern **40**, FIG. **6**. The side lobes in the patterns **50**, **52**, **54** may be minimized in the manner described in the aforementioned application titled, "Broadband Multimode Horn Antenna" by "multimoding" the center horn **10**. With the center horn **10** multimoded in this manner, the nine-horn array of FIG. **1** generates a beam having the H-plane pattern **56**, the E-plane pattern **58** and the diagonal plane pattern **60** shown in FIG. **5** wherein the size of the side lobes apparent in the corresponding patterns **50**, **52**, **54** are substantially reduced. As before, the shoulder width of the patterns **56**, **58**, **60** are each 19° which approximates that of the ideal pattern **40** for earth coverage from a synchronous satellite. In other applications such as the feed for a Cassegrain antenna, other power splits by the power divider **26** may be required and larger flare angles used depending on size of reflector and frequency.

What is claimed is:

1. An antenna system comprising a conductive center horn of predetermined size, said center horn having an input at one extremity and an aperture at the remaining extremity thereof; a plurality of no less than four and an integral power of two peripheral horns, each having an input at one extremity and an aperture at the remaining extremity thereof, each being symmetrical about a longitudinal axis and each being of a uniform size smaller than said predetermined size, said plurality of horns being disposed at uniform intervals about and at the same point along said center horn and aligned in the same direction as said center horn; means coupled to said input at said one extremity of said center horn for launching a first signal of predetermined frequency, phase, and power from said center horn; and means coupled to said respective inputs of said plurality of horns for simultaneously launching a second signal therefrom, said second signal having a frequency equal to said predetermined frequency, a power that is only a fraction of said predetermined power and a phase that is nominally 180° relative to said predetermined phase.

2. The antenna system as defined in claim **1** wherein the total area of said apertures of said plurality of horns is substantially three times the area of said aperture of said center horn.

3. The antenna system as defined in claim **1** wherein said aperture of said center horn and said apertures of said plurality of horns are in a common plane.

4. The antenna system as defined in claim **1** additionally including means disposed in said center horn for multimoding said center horn.

5. An antenna system for generating a predetermined antenna pattern in response to an applied signal, said system comprising a conductive conical center horn of predetermined size, said conical center horn having an input at one extremity and an aperture at the remaining extremity thereof; eight conductive conical peripheral horns, each having an input at one extremity and an aperture at the remaining extremity thereof and each being of a uniform size smaller than said predetermined size, said eight peripheral horns being disposed at uniform intervals about said center horn; and means coupled to said input of said conical center horn and to said respective inputs of said eight conical peripheral horns and responsive to said applied signal for launching a major portion of the power of said signal from said conical center horn as a wave in a TE_{11} dominant mode with a predetermined phase and for launching the remaining portion of the power of said signal equally from said eight peripheral horns as respective waves in TE_{11} dominant modes with a phase nominally 180° relative to said predetermined phase.

6. The antenna system as defined in claim **5** wherein the respective diameters of said eight peripheral conical horns equal 0.618 times the diameter of said aperture of said conical center horn.

7. The antenna system as defined in claim **5** additionally including means in said conical center horn for multimoding said conical center horn.

8. An antenna system for generating a predetermined antenna pattern in response to an applied signal, said system comprising a conductive conical center horn of predetermined size, said conical center horn having an input at one extremity and an aperture at the remaining extremity thereof; eight conductive conical peripheral horns, each having an input at one extremity and an aperture at the remaining extremity thereof and each being of a uniform size smaller than said predetermined size, said eight peripheral horns being aligned in the same direction as said center horn and disposed at uniform intervals thereabout with the apertures thereof in a plane common with said aperture of said center horn; first, second, third, fourth, fifth, sixth, and seventh magic tees, each of said magic tees having a shunt input arm and first and second output arms, said first and second output arms of said first, second, third and fourth magic tees being connected, respectively, to said inputs of said eight conical peripheral horns to launch signals of predetermined polarity therein, said first and second output arms of said fifth and sixth magic tees being connected to said shunt arms of said first, second, third, and fourth magic tees, and said first and second output arms of said seventh magic tee connected to said shunt arms of said fifth and sixth magic tees; and means including a power divider responsive to said signal and having outputs connected to said input of said conical center horn and said shunt arm of said seventh magic tee for directing a major portion of the power of said signal to said center horn and the remaining portion of the power of said signal to said shunt arm of said seventh magic tee.

9. The antenna system as defined in claim **8** wherein said power divider directs 95 percent of the power of said signal to said center horn and the remaining 5 percent thereof to said shunt arm of said seventh magic tee.

* * * * *