

[54] **MULTI-PURPOSE ANTENNA
EMPLOYING DISH REFLECTOR WITH
PLURAL COAXIAL HORN FEEDS**

[72] Inventors: **George M. Low**, Deputy Administrator of the National Aeronautics and Space Administration with respect to the application of; **Kenneth E. Woo**, 1621 Amberwood Dr., South Pasadena, Calif. 91030

[22] Filed: **May 12, 1970**

[21] Appl. No.: **36,531**

[52] U.S. Cl. **343/762, 343/777, 343/779, 343/786, 343/853**

[51] Int. Cl. **H01q 19/14**

[58] Field of Search **343/776, 777, 778, 779, 786, 343/762, 853**

[56] **References Cited**

UNITED STATES PATENTS

3,086,203 4/1963 Hutchison **343/786**

3,388,399 6/1968 Lewis **343/786**
3,508,277 4/1970 Ware et al. **343/786**

FOREIGN PATENTS OR APPLICATIONS

898,352 7/1944 France **343/779**

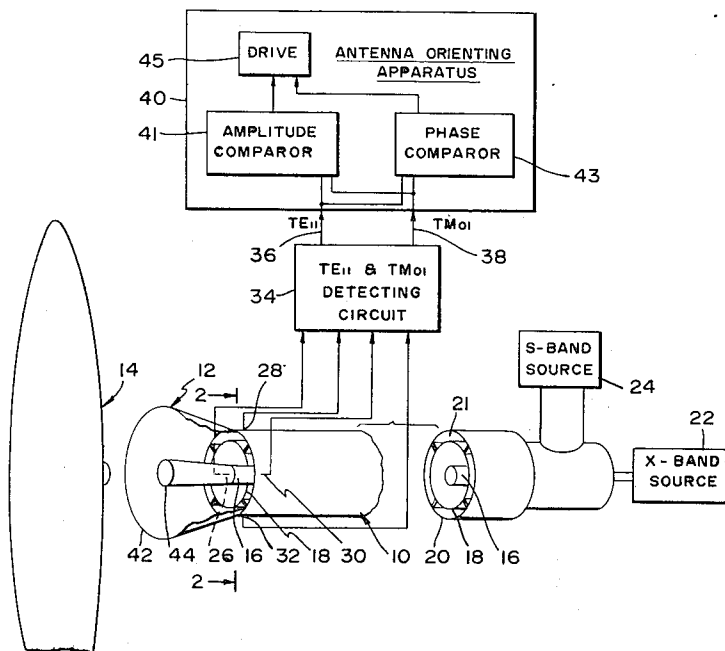
Primary Examiner—Eli Lieberman

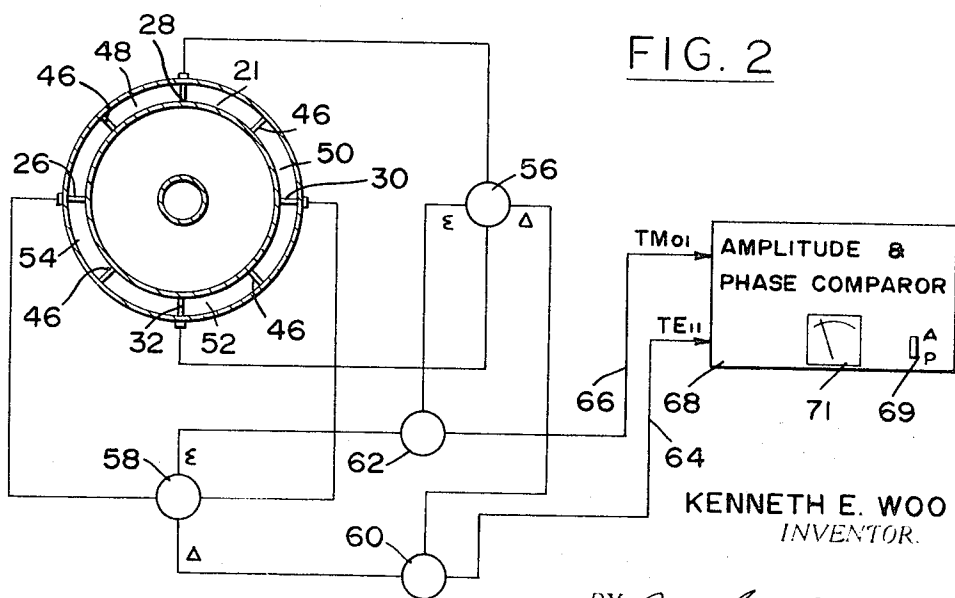
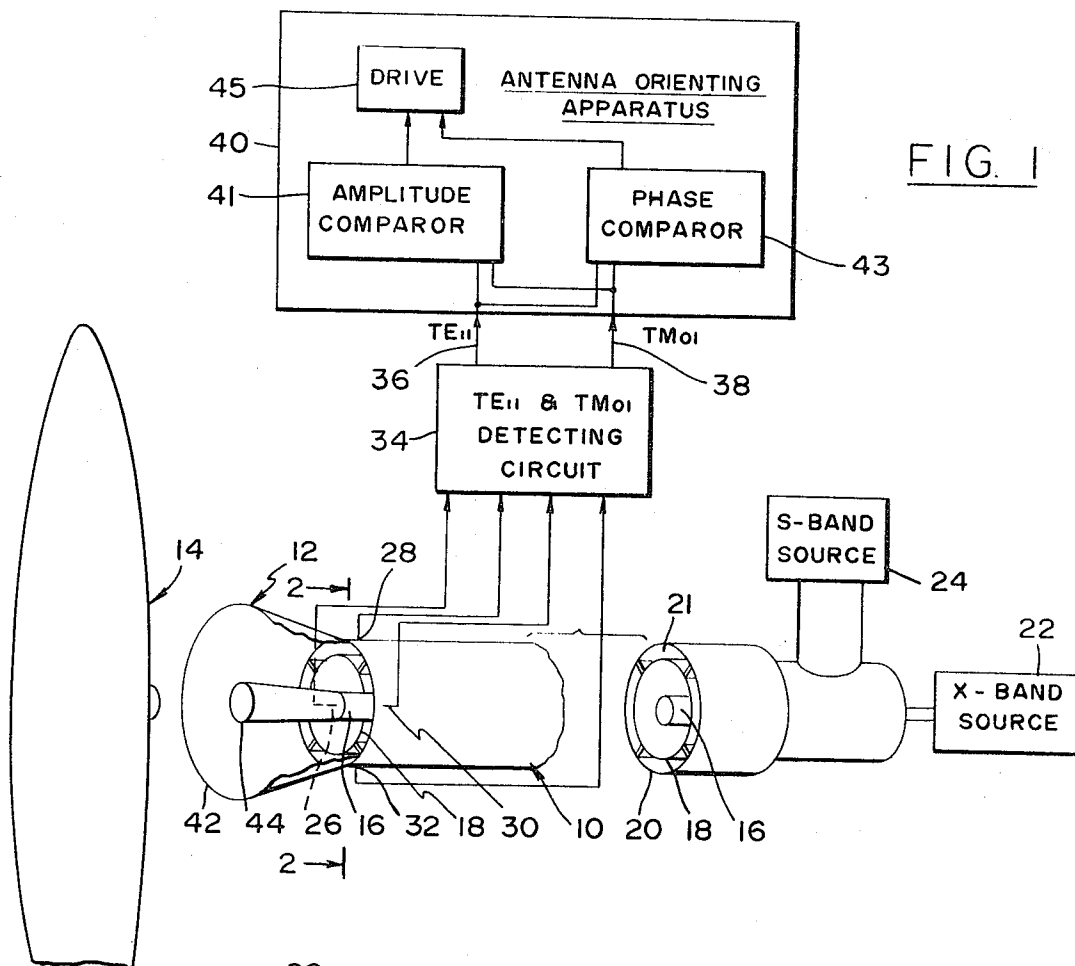
Attorney—J. H. Warden, Paul F. McCaul and John R. Manning

[57] **ABSTRACT**

A microwave antenna useful on a spacecraft, which utilizes a single dish reflector and single coaxial horn structure to transmit at two frequencies, and to receive signals at a third frequency that allow tracking. The horn structure includes a coaxial wave-guide with an inner pipe for transmitting X-band waves, an intermediate pipe, surrounding the inner pipe for transmitting S-band waves through the space between it and the inner pipe, and an outer pipe surrounding the intermediate pipe for receiving S-band tracking signals. An outer horn flares from the outer pipe and an inner horn flares from the inner pipe, to efficiently illuminate the dish reflector at both X and S bands.

7 Claims, 5 Drawing Figures

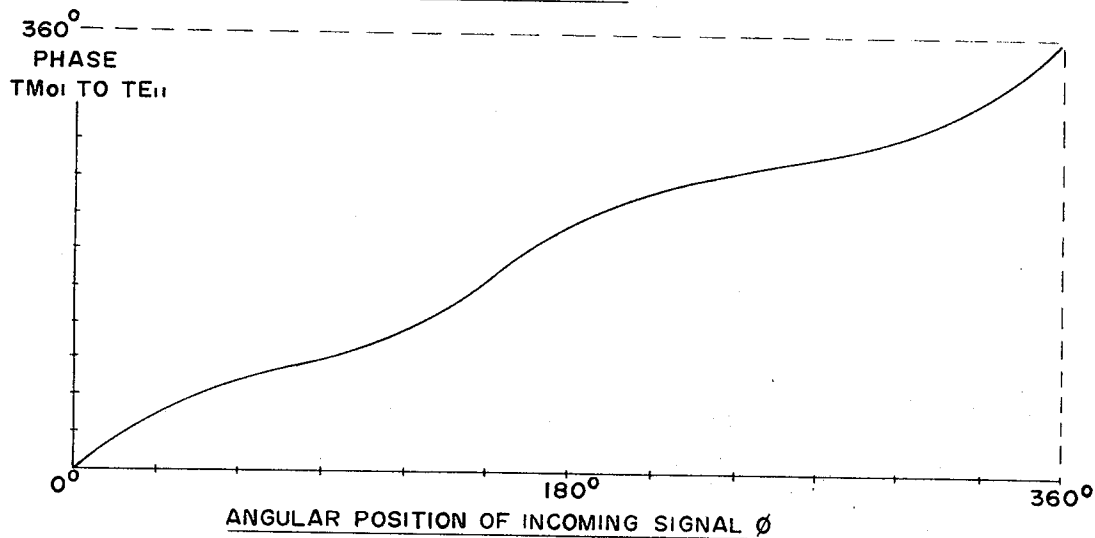
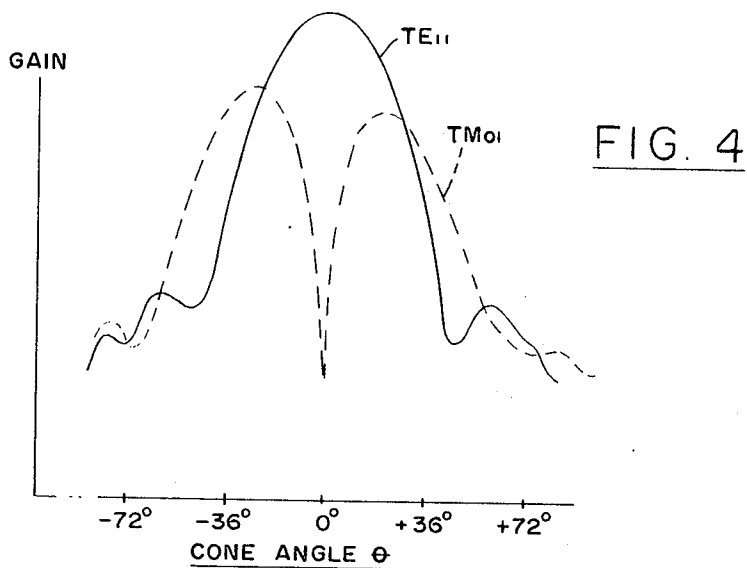
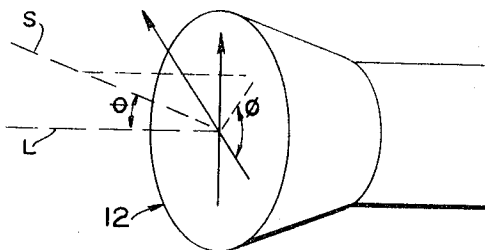




KENNETH E. WOO
INVENTOR.

BY *Paul F. McEul*
J. H. Warden
ATTORNEYS

FIG. 3



INVENTOR.
KENNETH E. WOO

BY *Paul F. McEwen*
J. H. Worden
ATTORNEYS

MULTI-PURPOSE ANTENNA EMPLOYING DISH REFLECTOR WITH PLURAL COAXIAL HORN FEEDS

ORIGIN OF THE INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568, (72 Stat. 435; 42 USC 2457).

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to antenna systems.

2. Description of the Prior Art

One type of spacecraft designed for deep space missions requires antennas for transmitting at S-band and X-band frequencies, and for receiving command signals and determining their direction of origin so that the craft can orient its antennas precisely towards the earth tracking station. This generally would necessitate three separate antenna structures, with three horns and possibly three reflectors. If such antenna capabilities could be combined in a single antenna structure, space and weight could be saved on the craft.

OBJECTS AND SUMMARY OF THE INVENTION

An object of the present invention is to provide a compact antenna structure having many antenna capabilities.

Another object is to provide a simple and highly efficient apparatus for tracking a microwave source.

In accordance with one embodiment of the invention, a microwave antenna structure is provided which combines tracking and transmission at two different frequencies in a single waveguide and horn assembly that can be utilized with a single reflector. The apparatus includes three coaxial pipes, the innermost pipe carrying X-band waves for transmission, the space between the intermediate and innermost pipe carrying S-band microwaves for transmission, and the space between the outermost and intermediate pipe carrying received S-band signals. One end of the pipes has a conical horn spreading out from the outermost pipe and directed towards a reflector to increase gain. In order to efficiently illuminate the reflector with X-band microwaves from the innermost pipe, a small additional horn is provided which flares from the innermost pipe towards the reflector.

The region between the intermediate and outermost pipes is utilized for tracking to determine the angle between the received beams which were transmitted by the earth station and the direction in which the antenna points, so that the antenna can be pointed precisely at the earth station. This is accomplished by employing four conductive plates which divide this outer waveguide region into four quasi-rectangular waveguides. When a circularly polarized wave transmitted by the earth station is received at this outer region, both TE_{11} and TM_{01} waves are generally propagated in the region. Four probes are positioned in the four quasi-rectangular waveguides to pick up these waves. The four probes are connected to a hybrid circuit which has two outputs, one being the TE_{11} component and the other TM_{01} component. The ratio of the amplitudes of these components indicates the error angle between the antenna pointing direction and the source of the signals (the direction of the earth station), while the phase between these two signals indicates the direction in which the antenna must be rotated to reduce the error angle. Signals representing these amplitude and phase relationships can be used to reorient the antenna.

The novel features of the invention are set forth with particularity in the appended claims. The invention will be best understood from the following description when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a partial perspective, partial schematic diagram of antenna apparatus constructed in accordance with the present invention;

FIG. 2 is a partial schematic diagram of the antenna apparatus, showing the circuit for tracking an incoming signal;

FIG. 3 is a partial perspective view of an antenna horn;

FIG. 4 is a graph showing the relationship between the amplitudes of the TE_{11} and TM_{01} components and the pointing cone error angle of the antenna; and

FIG. 5 is a graph showing the relationship between the phase difference of the TM_{01} and TE_{11} components and the angular direction of the pointing error.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As shown in FIG. 1, an antenna structure is provided for transmitting and receiving signals, including a waveguide assembly 10, a horn assembly 12 at one end of the waveguide assembly which serves largely as a radiating end, and a reflector 14 positioned opposite the horn assembly. The waveguide assembly 10 includes a circular inner tube 16 for carrying an X-band signal at a frequency such as 8,448 MHz, an intermediate tube 18 more than twice the diameter of the inner tube for carrying an S-band signal in the region between it and the small inner tube, of a frequency such as 2,295 MHz, and an outer tube 20 for carrying a received S-band signal of a frequency such as 2,115 MHz. An X-band source 22 generates X-band signals which pass through the inner tube for transmission of information while an S-band source 24 is coupled to the intermediate tube 18 to transmit information at S-band. The reason why both frequency bands are utilized in transmission is that while X-band allows more information to be transmitted and is more efficient, these waves cannot always penetrate earth's atmosphere. On the other hand, S-band signals generally can penetrate the earth's atmosphere even under adverse conditions, for receipt by an earth ground station.

The signal received in the tracking region 21 between the outer tube 20 and intermediate tube 18 enables tracking, so that the antenna can be pointed precisely toward the earth station which transmitted the signal. If the earth station transmits a circularly polarized signal of proper frequency, the received signal will produce TE_{11} components and TM_{01} components in the tracking region 21 between the outer pipe 20 and the intermediate pipe 18. In the absence of a circular horn, the TE_{11} and TM_{01} components will not be produced, and instead only TE_{10} waves will be produced in the tracking region 21 (then the structure would act as a four horn monopulse tracking system and three channels would have to be generated initially and dealt with). The relative strength of these components (TE_{11} and TM_{01}) and their relative phase can be utilized to determine the error cone angle between the earth station and the direction in which the antenna is pointing, as well as the direction in which the antenna must be moved for better alignment.

In order to detect the TE_{11} and TM_{01} components, four probes 26, 28, 30 and 32 are provided which project into the tracking region 21. The signals picked up by the four probes are fed to a detecting circuit 34 with one output 36 that delivers the TE_{11} components and another output 38 which delivers the TM_{01} component. These two outputs are connected to antenna orienting apparatus 40 which can rotate the antenna to point it more precisely towards the earth station which transmitted the tracking signal. The orienting apparatus 40 includes an amplitude comparator circuit 41 for determining the ratio of the two components to determine the cone angle of error as well as a phase comparator circuit 43 for determining the relative phase of two components to determine the direction in which the antenna must be reoriented to reduce the pointing error. The antenna orienting apparatus also includes a drive 45 which may operate gas jets or the like to reorient the antenna, or even the entire spacecraft in those cases where the antenna is rigidly fixed to the craft.

The two S-band signals which are carried by the antenna, one for transmitting and one for receiving, are close enough in frequency so that a single horn 42 can be employed to efficiently illuminate the reflector 14 with both frequencies. However, the X-band signal passing through the inner tube 16 has a frequency more than twice as great as either S-band frequency, and its beam width is too narrow to efficiently illuminate the reflector. In order to increase the beamwidth at X-band, an additional horn 44 is utilized, which flares from the outer end of tube 16. The horn 44 blocks a small portion of the radiating aperture for the S-band signal, but it greatly increases the efficiency of radiation of the X-band signal when the same reflector 14 is used for both frequency bands. It would be possible to obtain a greater beamwidth without the use of the second horn 44, by exciting various higher modes in the inner tube 16, through the use of discontinuities and the like. However, this would increase the complexity and weight of the antenna structure. The use of only the small additional horn 44 provides good overall efficiency in a simple and light structure. It may be noted that, although a reflector 14 is generally employed to increase gain, it is possible to dispense with this and radiate directly from the horns (but then a four horn monopulse tracking technique would have to be used for any tracking). Also, although the horn is shown located in front of the reflector, various telescope constructions can be used such as Cassegrain types wherein the horn energy is radiated by a subreflector towards the main reflector dish.

As shown in FIG. 2, the tracking region 21 is divided by four electrically conductive plates 46, into four quasi-rectangular waveguides 48, 50, 52 and 54. Each of the probes 26, 28, 30 and 32 is positioned at the center of one of these quasi-rectangular waveguides to detect the microwave signal therein. The TE_{11} and TM_{01} modes propagating through the tracking region can be separated by a hybrid circuit of the type shown in FIG. 2 which includes two hybrid rings or magic tees 56, 58, and two 3 db hybrids 60 and 62. The probes 28 and 32 are connected to two ports of one ring 56 while the other probes 26, 30 are connected to two ports of another ring 58. The difference signal port Δ from each ring 56, 58 is connected to 90°, 3 db hybrid 60 which delivers only the TE_{11} mode on line 64. The sum signal port Σ from each ring 56, 58 is connected to 0°, 3 db hybrid 62 which delivers the TM_{01} component on a line 66. Thus, the hybrid circuit delivers signals representing these two modes separately. In a laboratory set-up, these two signal components can be delivered to a comparator 68 that shows their relative amplitudes and phases. A switch 69 can be moved between either of two positions to indicate relative amplitude or phase on a meter 71. Knowledge about the relative amplitudes and phases can be used to determine the angular deviation or error of the antenna line of sight or boresight from the earth station, as well as the direction of that error.

FIG. 3 illustrates the horn 12 and a system of coordinates for indicating the cone angle θ and position angle ϕ which define the direction of an incoming signal S with respect to the line of sight L of the antenna. FIG. 4 illustrates the relationship between the amplitudes of the TE_{11} and TM_{01} modes as a function of the cone angle θ . It can be seen that the TM_{01} mode decreases rapidly towards a null as the cone angle θ decreases towards zero, that is, as the antenna becomes precisely aligned with the direction of the tracking signal. By calculating the ratio of the TE_{11} and TM_{01} components, or measuring the amplitude of the TM_{01} mode under conditions where the incoming signal is relatively constant, one can determine the approximate cone angle. FIG. 5 illustrates the relative phases of the TM_{01} and TE_{11} modes as the position angle ϕ varies. It can be seen that the phase difference of the components is proportional to the position angle ϕ , and a comparison of the phases indicates the position angle at which the incoming signal is being received when the antenna is not aligned with the direction of the incoming tracking signal. Circuitry is well known which can be utilized to automatically calculate the ratio of magnitudes and relative phases of the two components to drive a reorienting system that reorients the antenna to point directly towards the source of the tracking signals.

An antenna structure of the type shown in FIG. 2 has been constructed, using a Hewlett Packard Model HP8410 network analyzer as the amplitude and phase comparator 68. Microwaves were directed at the structure at various positions relative to the pointing direction of the structure, and graphs were made of the types shown in FIGS. 4 and 5 (where only an outer horn 12 but no inner horn 44 was present). FIG. 4 represents the signal levels for the two components which were obtained while FIG. 5 represents the phase relationships which were obtained at the various position angles. It may be noted that in an ideal case, the graph of FIG. 5 would be a straight line, and in FIG. 4 the TM_{01} mode would achieve a null at a zero degree cone angle.

Thus the invention provides a compact antenna structure having multiple capabilities, including the ability to transmit at two widely different frequencies and to receive at still another frequency. The invention also provides an improved tracking system for detecting the direction of a tracking signal.

Although particular embodiments of the invention have been described and illustrated herein, it is recognized that modifications and variations may readily occur to those skilled in the art and, consequently, it is intended that the claims be interpreted to cover such modifications and equivalents.

What is claimed is:

1. Apparatus for indicating the pointing error of an antenna from a source of circularly polarized waves comprising:
 - a signal detecting structure including a circular coaxial waveguide with inner and outer coaxial pipes, and a plurality of conductive plates extending radially between said pipes;
 - a plurality of probes spaced about said waveguide for detecting transverse electric and magnetic waves therein;
 - first means coupled to said probes for deriving the TE_{11} component and deriving the TM_{01} component in said waveguide; and
 - second means coupled to said first means for generating signals indicating the relative magnitudes and relative phases of said TE_{11} and TM_{01} components.
2. The apparatus described in claim 1 including:
 - antenna orienting means responsive to the presence of a predetermined ratio of the TM_{01} component to the TE_{11} component, for rotating said signal detecting structure in a direction dependent upon the phase difference between the TM_{01} and TE_{11} components.
3. Apparatus for indicating the pointing error of an antenna from a source of circularly polarized waves comprising:
 - a circular coaxial waveguide with inner, intermediate, and outer coaxial pipes;
 - a first circular horn extending from said outer pipe of said waveguide;
 - a second horn smaller than said first horn extending from said inner pipe;
 - a reflector of larger diameter than said first horn positioned opposite said first horn, said second horn extending from said inner pipe towards said reflector;
 - a plurality of probes spaced about said waveguide for detecting transverse electric and magnetic waves therein;
 - first means coupled to said probes for deriving TE_{11} and TM_{01} components in said waveguide; and
 - second means coupled to said first means for generating signals indicating the relative magnitudes and relative phases of said TE_{11} and TM_{01} components.
4. An antenna comprising:
 - a reflector dish;
 - a coaxial waveguide extending toward said dish, said waveguide having inner, intermediate, and outer guides, said inner guide less than about one-half the diameter of said outer guide;
 - a first horn flaring out from said outer guide toward said dish;
 - a second horn flaring out from said inner guide toward said dish; and
 - a plurality of probes disposed about the annular space between said outer and intermediate guides, for enabling the detection of the TE_{11} and TM_{01} modes therein.

5

5. A microwave antenna structure comprising:
a coaxial waveguide having inner, intermediate, and outer coaxial pipes, and having a radiating end;
first means for generating microwaves of a first frequency coupled to said outer pipe;
second means for generating microwaves of a second frequency higher than said first frequency coupled to said inner pipe;
a common dish reflector located opposite said radiating end of said coaxial waveguide; and
a plurality of conductive plates extending radially between two of said pipes and parallel to the axis of said coaxial waveguide, for dividing the coaxial area between the two pipes into a plurality of quasi-rectangular waveguides.
6. A microwave structure comprising:
an antenna structure including a coaxial waveguide having inner and outer coaxial pipes, and a circular horn flaring outwardly from an end of said outer pipe;

6

- four conductive plates extending radially between the inner and outer pipes and parallel to the axis of said coaxial waveguide, for dividing the coaxial area into four quasi-rectangular waveguides that each subtend an angle of approximately 90° about the axis of said waveguide;
four probe means, each disposed in said quasi-rectangular waveguides for detecting microwaves therein; and
means coupled to said probe means for deriving first and second signals respectively representing the relative amplitude and relative phase of TE_{11} and TM_{01} waves in the coaxial region between said pipes.
7. The structure described in claim 6 including:
antenna orienting means responsive to said first and second signals, for reorienting said antenna structure upon the detection of a predetermined ratio of said TM_{01} and TE_{11} waves, in directions dependent upon the phase difference between said TE_{11} and TM_{01} waves.

* * * * *

20

25

30

35

40

45

50

55

60

65

70

75