

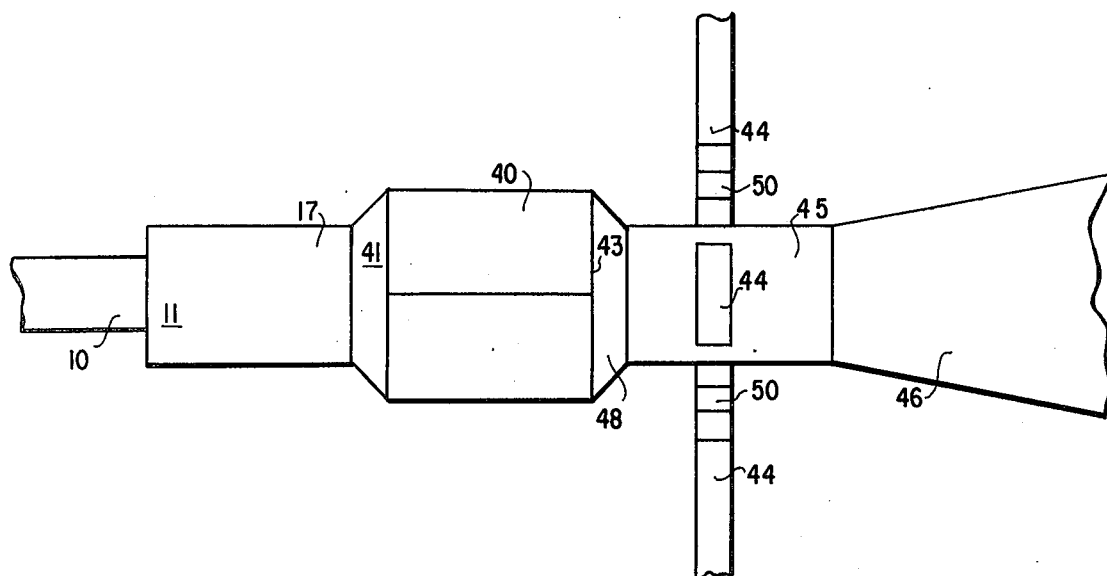
- UNITED STATES PATENTS

3,373,431	3/1968	Webb.....	343/786
3,530,483	9/1970	Pierrot.....	343/786
3,388,399	6/1968	Lewis.....	343/786 X
3,383,688	5/1968	Renaudie.....	343/786 X
3,369,197	2/1968	Giger et al.	343/786 X
3,560,976	2/1971	Foldes.....	343/772 X
3,423,756	1/1969	Foldes	343/786 X

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A feed system for autotracking antennas, in which the transmit channel and the receive sum and difference channels are independently controllable in that each is isolated from the other and the impedance match of any one is adjustable without disturbing the other two. The receive wave modes, both sum and difference, are propagated along a first section of waveguide from the antenna, wherein the receive channel energy is extracted near an abrupt junction with a second waveguide section designed to support only sum wave mode propagation. The sum mode is extracted without need for hybrids. The transmit feed and the receive feed lines cooperate to provide built-in diplexer action through appropriate selection of waveguide dimensions for rejection of transmit frequencies from the receive channel and inclusion of band pass filters for rejection of receive frequencies from the transmit channel.

16 Claims, 9 Drawing Figures



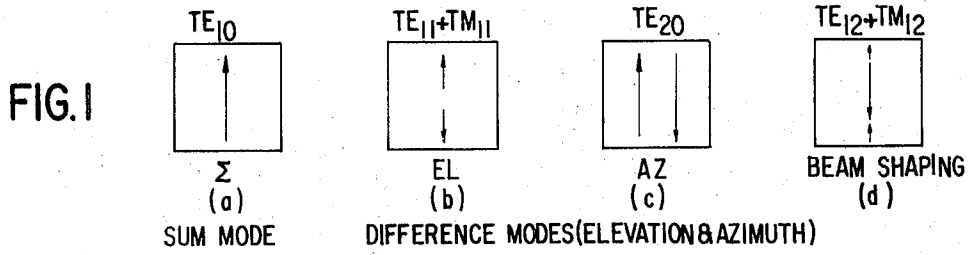
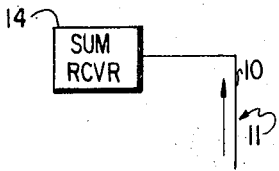
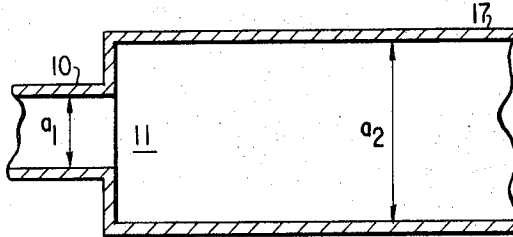
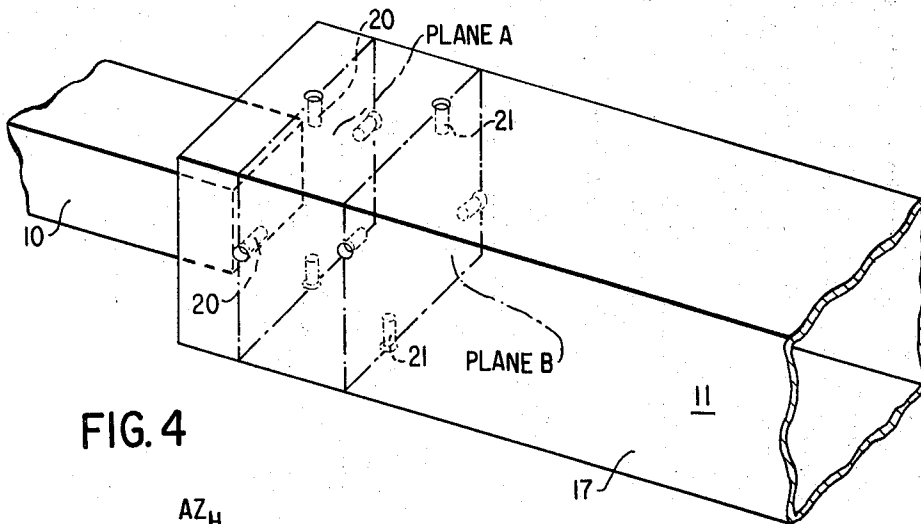
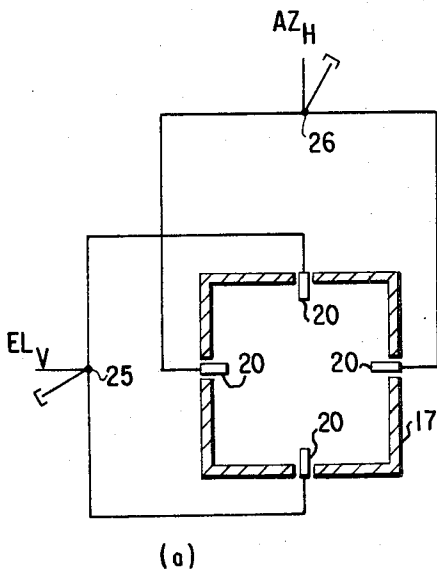
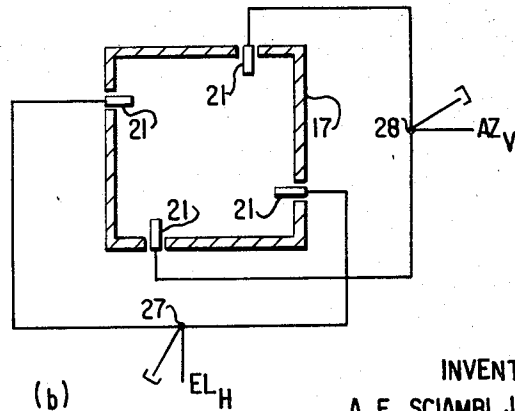


FIG. 5

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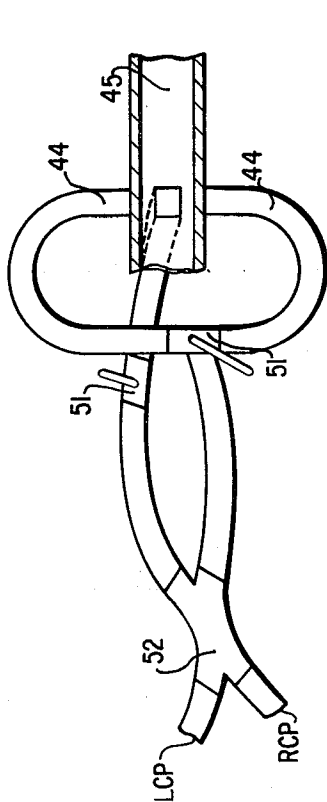


FIG. 9

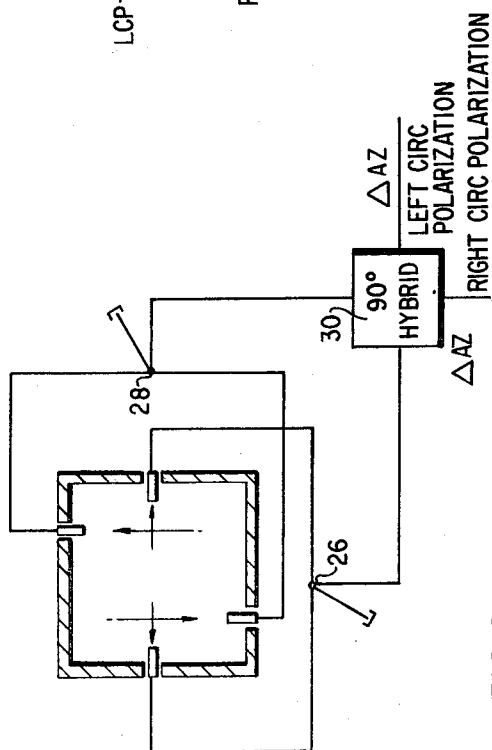


FIG. 6

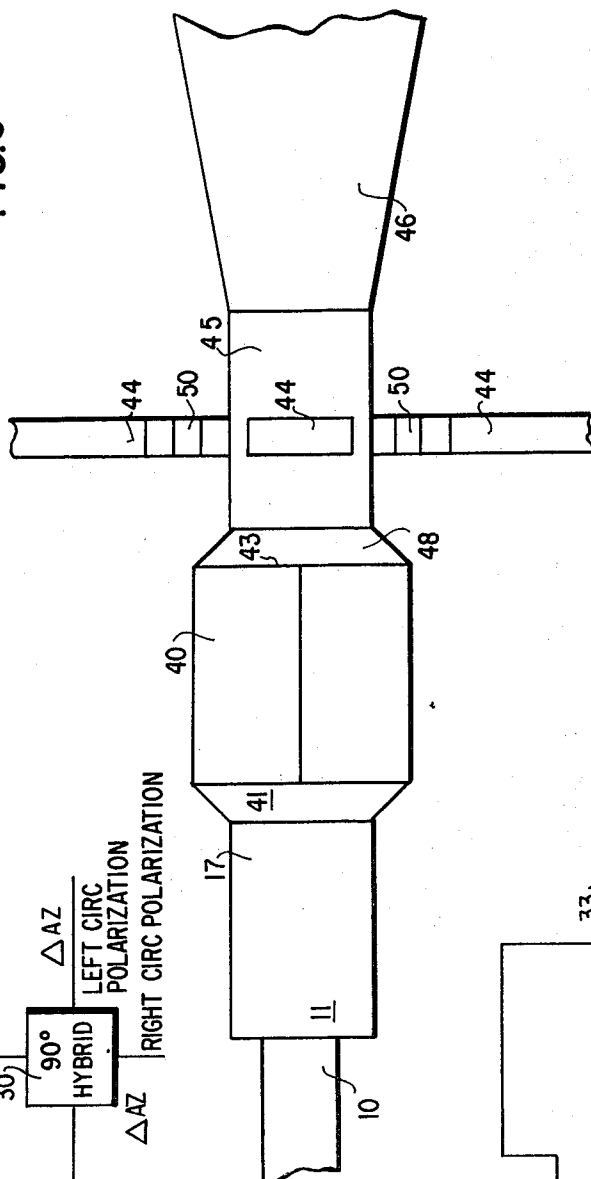


FIG. 8

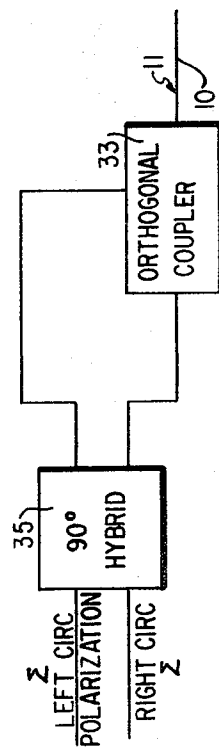


FIG. 7

INDEPENDENT MODE ANTENNA FEED SYSTEM

BACKGROUND

1. Field of the Invention

The present invention relates generally to antennas, and is particularly directed to feed arrangements for autotracking antenna systems.

2. Discussion of the Prior Art

In autotracking antenna systems, the difference receiver is nulled for target azimuth and elevation information to permit automatic tracking of the target along the boresight axis. Sum channel information is fed to a separate sum receiver for provision of a typical target field display. The feed arrangement for the antenna is critical to the autotracking system, in that the feed must provide essentially independent control of aperture illumination if efficient operation in sum and difference modes is to be achieved. Heretofore, the desired independent control of the sum and difference channels has been achieved at the expense of compromising the two mode channels and using hybrids in the feed arrangement to generate the sum pattern in order to also generate the difference pattern.

SUMMARY OF THE INVENTION

It is a principal object of the present invention to provide an automatic tracking feed in which the sum and difference modes are isolated in an improved manner.

Another object of the invention is to provide feed arrangements for automatic tracking antennas in which sum and difference channels are independently controlled and the sum pattern can be generated without the use of hybrids.

According to a principal feature of the invention, a first section of a waveguide of the feed arrangement is designed to pass virtually only the sum mode, and a second section of the same waveguide is stepped abruptly to a larger dimension for propagation of both the sum and the difference modes. The difference mode energy is then extracted at cross sectional planes located at quarter wavelengths (of the appropriate wave energy in the guide) from the point of the abrupt step in the waveguide section of larger dimension, to obtain target elevation and azimuth information, respectively. In a preferred embodiment of the invention, probes (exciters) extending into the waveguides at these planes are utilized to extract the desired difference wave modes. These probes are coupled to hybrids, into the sum ports of which a considerable amount of sum mode energy is likewise coupled. In order to recapture that energy and thereby maintain high sum channel efficiency, the sum port of each hybrid is short circuited at an appropriate point to reflect the sum mode energy back into the guide and thence into the smaller dimension section (i.e., the main channel).

BRIEF DESCRIPTION OF THE DRAWINGS

In describing an exemplary embodiment of the invention, reference will be made to the accompanying figures of drawing, in which:

FIGS. 1(a), (b), (c), and (d) are diagrammatic indications of certain wave propagation modes in a square waveguide;

FIG. 2 is a circuit diagram of the waveguide connection to a receiver;

FIG. 3 is a fragmentary cross-sectional view of a stepped waveguide taken in a plane containing the axis of the waveguide;

FIG. 4 is a fragmentary perspective view of the waveguide of FIG. 3;

FIGS. 5(a) and (b) are sectional views of the waveguide of FIG. 4 taken along planes A and B, respectively, showing the output coupling for difference channel probes in those planes;

FIG. 6 is a sectional view of the waveguide of FIG. 4 along a plane perpendicular to the axis of the waveguide, showing a combined difference channel output coupling for circular polarization;

FIG. 7 is a circuit diagram showing output coupling of the sum channel for circular polarization;

FIG. 8 is a fragmentary side view of a length of the antenna feed system providing transmit and receive channel coupling to a horn; and

FIG. 9 is a fragmentary perspective view, partly in section, of the connection of transmit lines for the feed system of FIG. 8, to provide circular polarization.

DETAILED DESCRIPTION OF THE INVENTION:

A preferred embodiment of an autotracking feed in accordance with the present invention, for operation with a single linear, two orthogonal linear, or circularly polarized Cassegrain antenna configuration in the S-band of frequencies, will be described.

The wave propagation modes of interest in a square waveguide (multimode) are shown in FIG. 1. The sum (Σ) mode is the TE_{10} wave (FIG. 1(a)), the difference (Δ) modes are the $TE_{11} + TM_{11}$ wave, for elevation, and the TE_{20} wave, for azimuth (FIGS. 1(b) and (c), respectively), and beam shaping in the E plane is obtained with the $TE_{12} + TM_{12}$ wave (FIG. 1(d)). For the sake of example, a frequency range of 1,750 to 1,850 MHz will be assumed for transmit, and a frequency range of 2,200 to 2,300 MHz will be assumed for receive. Because of the wide frequency spread (low to high), it is desirable to separate the transmit and receive functions and thereby eliminate any requirement of wideband hybrids. Such separation achieves a bandwidth reduction of from about 30 percent to about 5 percent, for the frequencies noted above.

For the receive function, a first section 10 of waveguide 11 is coupled to a sum receiver 14 (FIG. 2), without need for the conventional hybrids in the sum channel path. In order to propagate the TE_{10} (sum, FIG. 1(a)) mode as the dominant wave in the aforementioned receive range, the input guide section (main channel) 10 is selected to be a square section of waveguide having a dimension of a_1 of 3.00 inches. A square waveguide having that dimension will permit transmission of the TE_{10} mode above a cutoff frequency (f_c) of 1,970 MHz, whereas all higher order modes are cut off at 2,340 MHz. Section 10 may be an odd multiple of a quarter wavelength long.

Waveguide 11 is abruptly stepped at an axially symmetrical junction (FIG. 3) to a second square section 17 of larger dimension than first section 10. In particular, in order to support propagation of the TE_{10} , $TE_{11} + TM_{11}$, and TE_{20} modes in the frequency band of interest, waveguide section 17 is selected to have a dimension a_2 of 5.61 inches. With that dimension of waveguide, the next higher mode, the $TE_{12} + TM_{12}$ wave, has a cutoff frequency of 2,340 MHz. Hence,

waveguide section 17 adequately supports the difference modes and it is merely necessary to extract that energy while passing the sum mode energy to waveguide section 10. In achieving this extraction of difference mode energy, the observation is made that waveguide section 10 is cut off (by design) as far as the difference modes are concerned, and the latter section thus presents an effective short circuit near its junction with guide section 17. Placement of exciters in planes one-quarter wavelength back (or any odd multiple thereof) from the junction of the two waveguide sections, in guide section 17, for the guide wavelength of each of the difference waves ($TE_{11} + TM_{11}$ mode and TE_{20} mode) will serve to couple energy from the guide at those respective wavelengths.

The average quarter wavelength (in the guide) for the $TE_{11} + TM_{11}$ mode is 1.78 inches and for the TE_{20} mode is 4.58 inches, in the frequency band of interest. Exciters in the form of probes 20 (FIG. 4) project into guide section 17 at the midpoint of each side of the guide in a plane A located 1.78 inches from the junction of guide sections 10 and 17, to extract the $TE_{11} + TM_{11}$ mode. Similarly, another set of probes 21 is arranged in a plane B located 4.58 inches from the junction, with each of probes 21 projecting into guide section 17 through a respective side wall, to extract the TE_{20} mode.

The probes should be positioned in the side wall of the waveguide to extract maximum energy from the guide in the mode of interest. Thus, for extraction of the $TE_{11} + TM_{11}$ mode, each of probes 20 is located at the midpoint of the respective side wall, in plane A; while for extraction of the TE_{20} mode, each of probes 21 is located approximately a quarter of the distance from an edge of the respective side wall, in plane B. It is to be understood, however, that other probe configurations might alternatively be used, taking into account the type of probe, i.e., voltage and/or current to be utilized. For example, to extract the TE_{20} mode, two voltage probes 21 might be located in each of the top and bottom walls of guide section 17, one-quarter of the distance from each edge, with no probes in the remaining two walls.

Oppositely positioned probes in each diverse set 20, 21 are coupled to input ports (Σ and Δ) of respective hybrids 25, 26, 27, 28, as shown in FIGS. 5(a) and 5(b), to derive the desired outputs for application to the difference receivers (elevation and azimuth, or bearing). Thus, a voltage component of elevation information is obtained from the output port of hybrid 25, the current component of azimuth information is obtained from hybrid 26, the current component of elevation information is obtained from hybrid 27, and the voltage component of azimuth information is obtained from hybrid 28.

It also happens that a considerable amount of energy from the TE_{10} mode is coupled by the probes into the sum port of each hybrid. In order to achieve high sum channel efficiency, it is essential that this energy be recovered. This desirable goal is readily accomplished by short circuiting the sum port of each hybrid at an appropriate point to reflect the coupled sum mode energy back into guide section 10. Specifically, if the short circuits are placed a quarter wave multiple back along the sum port from the hybrid, virtually all of the energy coupled from the sum mode is reflected and recovered.

Furthermore, by maintaining the length of the lines (e.g., coaxial cable) from the probes to the respective hybrid as short as is feasible, the energy reflected from the short circuit will remain in the proper phase for the separated, narrow (about 5 percent) receive band. Each hybrid may be replaced by a simple power divider if these lines are restricted to a multiple of a half wavelength of the TE_{10} wave, since under that condition the short circuit is effectively built into the system.

The difference channels obtained using the arrangement of FIG. 5 may be combined in an external 90° hybrid 30, as shown in FIG. 6, to produce circular polarization. To eliminate or at least substantially minimize any effect of this configuration on the dominant mode propagation in waveguide section 10, it is merely necessary to provide proper matching. For example, if power dividers are utilized in the feed circuit, rather than hybrids 26 and 28 (FIG. 6), the difference channels can be matched by stub tuners (not shown) on the output of the power dividers. Preferably, external polarizers are used with hybrid 30, instead of the internal polarizers in each port which is typical of the four port hybrid design. In this way, there is eliminated the source of boresight shift of the secondary beam which could otherwise occur as a result of amplitude unbalance attributable to lack of precise matching (each to the other) of the internal polarization ellipse of each port.

Since the waveguide section 10 supports only the TE_{10} mode, any impedance matching elements placed in that section have no effect on the difference channels. As shown in FIG. 7, circular polarization is obtained in the sum channel by extracting the TE_{10} mode through an orthogonal coupler 33 and supplying the sum outputs to input ports of a 90° hybrid 35 having external polarizers associated therewith. Thus, the sum channel is controlled independently of the difference channels.

The remaining feed circuit, the transmit channel, is separated from the receive channel by provision of a four port waveguide section 40 (FIG. 8) which is connected via a smooth transition guide member 41 to waveguide section 17. Each of the four square waveguides in section 40 is designed to cut off at a frequency below the receive frequency band but above the transmit frequency band. For the transmit frequency band noted earlier, a suitable cutoff frequency is 1,910 MHz, achieved by selecting each guide in section 40 to be approximately 3.1 inches in inside dimension. The waveguide section is an odd number of quarter wavelengths long at the center of the receive frequency band in the guide for reasons to be discussed presently. At junction 43, the waveguide section 40 presents an effective short circuit to the transmit frequency supplied by four transmit lines 44 coupled, at an odd number of quarter wavelengths of the transmit frequency, to a waveguide section 45 between the throat of a horn 46 and the transition guide section 48 forming junction 43 with four port guide sections 40. The odd multiple of quarter wavelength spacing between the transmit lines and the short circuit junction assures a good impedance match. The length of the four port waveguide section 40 is selected to provide self matching to the receive band, i.e., with input and output junctions separated by an odd multiple of quarter

wavelengths to cancel reflections from the two junctions within the receive band.

Virtually all of the energy within the transmit frequency band is supplied to the horn 46, because this is the matched path of that band. Four port waveguide section 40 has an attenuation of 18 db at the transmit frequency (and less than 0.01 db at the receive band), with the specified dimensions and frequency bands. Thus, any transmit signal energy appearing at the difference channel probes (20, 21) is of the order of 25 db down from the energy being fed to the horn. This affords built-in protection of the difference channel probe from overheating. The received sum signal tends to couple to the transmit lines 44 on reception. However, some natural rejection is obtained as a consequence of the location of the effective short circuit attributable to four port section 40, presenting a poor impedance match to the coupled received sum signal frequency at the transmit lines. Additional rejection of this coupled signal is obtained by placement of a band pass filter 50 (for passing the transmit band) in each transmit line. The effective short circuit of the filter is located to reflect the coupled energy back into the main receive channel.

Horn 46 is a corrugated horn with a square aperture. It operates over the entire frequency band (low to high) of 1,750 to 2,300 MHz.

The four transmit lines 44 are connected by way of magic tees 51 (FIG. 9) and short slot hybrids 52 to give the required circular polarization.

The dimensions of waveguide 10 are selected as set forth above so that the transmit frequency is beyond cut-off and acts as part of a built-in diplexer presenting 36 db per foot of attenuation at the transmit frequency while resulting in only 0.009 db per foot of attenuation at the receive sum frequency band. The other part of the diplexer is formed by the filters 50 in transmit lines 44.

Tuning screws, posts, irises, and the like can be located in lines 44 to provide an impedance match at the transmit band without affecting the other channels.

While a preferred embodiment of the invention has been disclosed herein, it will be apparent that variations and modifications thereof will readily suggest themselves to those skilled in the art to which the present invention pertains from a consideration of the foregoing description, without departing from the spirit of the invention. Accordingly, the scope of the invention is to be determined from the following claims.

What is claimed is:

1. A feed arrangement for autotracking antenna systems, said feed arrangement having a main receive channel for energy in a receive frequency band incident on the antenna, said main receive channel comprising

a waveguide characterized by a section of large inside transverse dimensions and a section of relatively smaller inside transverse dimensions, said sections joined together at an abrupt axially symmetrical junction,

said smaller dimensioned waveguide section selected to support virtually only sum mode propagation, said larger dimensioned waveguide section selected to support both sum and difference mode propagation,

means for feeding energy in said receive band from said antenna into said larger dimensioned waveguide section, and

means located in a plane an odd number of quarter wavelengths from said junction in said larger dimensioned waveguide section, at approximately the wavelength of the difference mode wave, for extracting the difference mode energy from said waveguide.

2. The feed arrangement according to claim 1 wherein

said larger dimensioned section supports two diverse difference modes, and wherein

second extracting means is located in a plane an odd number of quarter wavelengths back from said junction in said larger dimensioned waveguide section, at approximately the wavelength of the second of the difference mode waves, for extracting energy in the second difference mode from said waveguide.

3. The feed arrangement according to claim 2, further including

means for combining the difference mode energy extracted from said waveguide by both of said extracting means, to derive information regarding the location of a target being tracked by the autotracking antenna system.

4. The feed arrangement according to claim 3, further including means for removing sum mode energy from said smaller dimensioned waveguide section after passage of the sum mode energy through said larger dimensioned waveguide section.

5. The feed arrangement according to claim 4, wherein said combining means includes

means for rejecting sum mode energy coupled into the difference mode extracting means, for recovery of said coupled energy by said means for removing sum mode energy.

6. The feed arrangement according to claim 5, further including

means coupled to said extracting means and to said removing means, for circular polarization of the sum and difference signals.

7. The feed arrangement according to claim 1, wherein

said energy feeding means includes

means for supplying energy in a transmit frequency band to said antenna, and

means for isolating energy in the transmit band from the receive channel and for isolating energy in the receive band from the transmit channel.

8. The feed arrangement according to claim 2, wherein

each of said extracting means includes energy absorbing probes projecting into said larger dimensioned waveguide section.

9. An antenna feed system for independent control of sum and difference channels, comprising

first and second serially connected electromagnetic wave transmission lines constructed and arranged to receive energy absorbed by an antenna in a predetermined receive frequency band and to support wave modes of propagation associated with sum and difference information in the absorbed energy,

said second transmission line constructed and arranged to receive energy passing through said first transmission line and to support only the wave propagation mode associated with the sum information,

means between said first and second transmission lines for preventing the entry of the wave propagation modes associated with the difference information from said first transmission line into said second transmission line,

means coupled to said first transmission line for extracting energy from the wave propagation modes associated with the difference information, and

means coupled to said second transmission line for extracting energy from the wave propagation mode associated with the sum information.

10. The antenna feed system of claim 9, further including

a third transmission line connecting said first transmission line to said antenna,

a fourth transmission line connected to said third transmission line for supplying power in a transmit frequency band to said antenna, and

means associated with said third and fourth transmission lines for isolating the transmit channel from the receive channel to retard energy transfer therebetween.

11. The antenna feed system of claim 9 wherein said first and second transmission lines are waveguides.

12. The antenna feed system of claim 11 wherein said means between said first and second transmission lines is an axially symmetrical abrupt waveguide junction presenting an effective short circuit to the wave propagation modes associated with the difference information.

13. The antenna feed system of claim 12 wherein the sum mode is the TE_{10} mode, and the difference modes are the $TE_{11} + TM_{11}$ mode and the TE_{20} mode.

14. The antenna feed system of claim 13 wherein

said means coupled to said first transmission line for extracting energy comprises

a first set of probes projecting into the waveguide in a plane located an odd number of quarter wavelengths from said junction, at the guide wavelength for the $TE_{11} + TM_{11}$ mode, for absorbing energy from that mode, and

a second set of probes projecting into the waveguide in a plane located an odd number of quarter wavelengths from said junction, at the guide wavelength for the TE_{20} mode, for absorbing energy from that mode.

15. The antenna feed system of claim 11 wherein said fourth transmission line includes wave filter means for passing said transmit frequency band while rejecting frequencies outside said transmit frequency band,

said first and second transmission lines having dimensions selected to reject said transmit frequency band while passing said receive frequency band, and cooperating with said wave filter means in said fourth transmission line to act as a built-in diplexer.

16. The antenna feed system of claim 10 wherein each of the transmit channel and the receive sum and difference channels has an impedance match at its respective frequency band which is independent of the impedance match presented by the others of said channels at their respective frequency bands.

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