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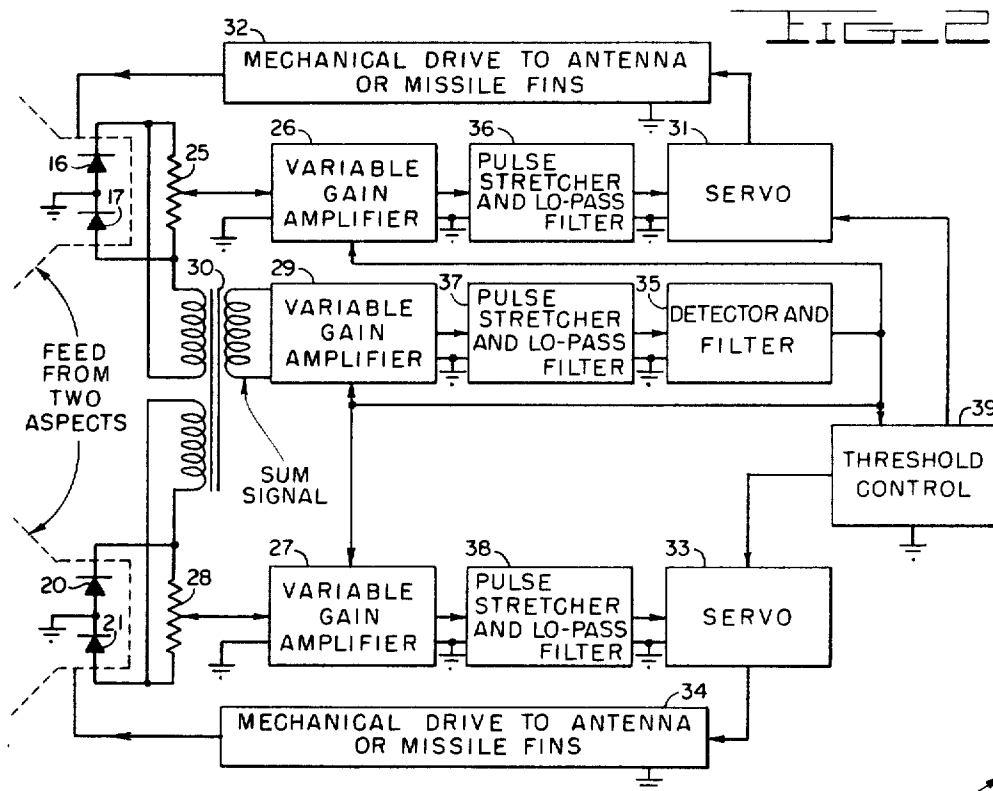
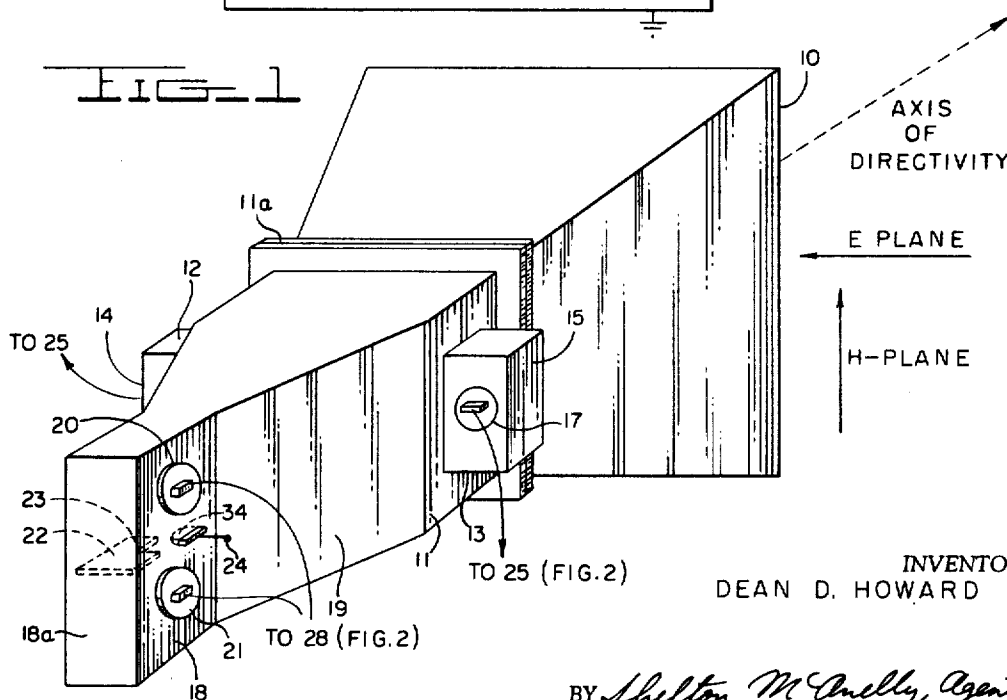
D. D. HOWARD

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SIMPLIFIED SINGLE-HORN MONOPULSE TRACKER

Filed May 23, 1962

2 Sheets-Sheet 1



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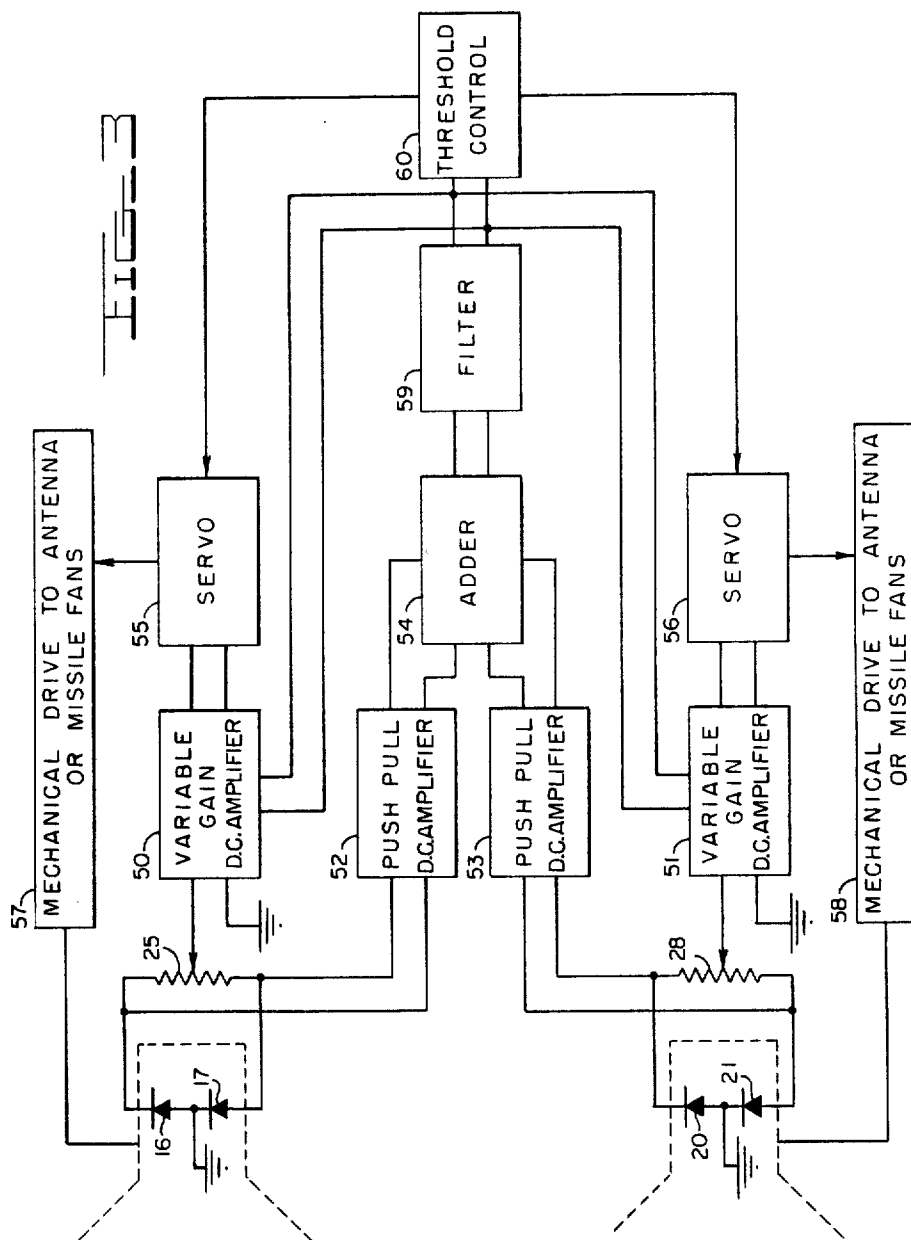
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SIMPLIFIED SINGLE-HORN MONO-PULSE TRACKER

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Filed May 23, 1962, Ser. No. 197,831

7 Claims. (Cl. 343—113)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to antenna systems in general and in particular to antenna systems having directive properties such as are normally desired for a direction sensing device or a radar system wherein various sum and difference signals are derived and utilized for determining the direction of a distant object or signal source.

In systems of the foregoing types and particularly with the so-called "Monopulse Radar System" in which various instantaneous sum and difference signals provide information as to the precise direction of a distant object signal source, it is usually desired that the information signals be derived and handled in as simple a manner as is possible consistent with the level of sensitivity desired.

An early system of the simultaneous lobing type is shown in U.S. Patent 2,929,056 which employs a plurality of antennas having slightly divergent axes in which sum and difference signals are derived simultaneously in azimuth and elevation planes indicative of direction of a distant energy return object.

In certain instances the more compact horn system described in application Serial No. 780,175 filed December 12, 1958 of Bernard L. Lewis, entitled Antenna Feed System, has advantages. The Lewis form of antenna makes it possible to replace the multi-horn assembly of Page with a single horn assembly having plural outputs which are substantially the same as the signals provided by the multi-horn assembly of the Page antenna.

A further development in the overall system which is frequently advantageous, either because of simplicity or because of certain advantages in connection with associated amplifiers, is described in application Serial No. 132,269, filed August 14, 1961, of Dean D. Howard for Balanced Channel Monopulse Tracking System. This invention improves the method of handling the necessary "difference" signals through amplifier devices by employing instead of the conventional separate "sum" and "difference" signals, which are normally of vastly different relative amplitude, "first" signals equal to the "sum minus the difference" and "second" signals equal to the "sum plus the difference," all of this separately for each plane, azimuth and elevation. The result is that these "first" and "second" signals are of very nearly the same amplitude and are more readily handled without distortion in identical signal paths or identical amplifiers operative in similar regions of their characteristics avoiding variation in the signal handling characteristics as regards phase shift, strong signal blocking, and the like. One undesirable characteristic of the afore-mentioned Howard device is that it introduces some additional complexity in the combining circuits necessary to derive the "sum plus difference" and "sum minus difference" signals and, since the effort is always toward obtaining devices of lesser complexity among other features, there is a definite desirability of providing a system such as that of the afore-mentioned Howard application which provides simplification without sacrifice of other desirable characteristics.

Accordingly, it is an object of the present invention to provide an antenna system in which "sum-minus-difference" signals and "sum-plus-difference" signals are derived in a simple manner.

Other objects and many of the attendant advantages of

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this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. 1 shows a general view of a feed system embodying the teachings of the present invention;

FIG. 2 shows a simplified monopulse radar system employing the apparatus of FIG. 1 as typified in a missile guidance application with A.-C. signal handling apparatus;

FIG. 3 is basically the same as FIG. 2 showing the particular relationship of components in a radar system where D.-C. signal handling is desired, such as in the case of tracking CW signals.

With reference now to FIG. 1 of the drawing, the apparatus shown therein represents a complete radio frequency end of a direction sensitive radar receiver system. This system would ordinarily be used in conjunction with additional circuitry of FIG. 2 intended for operation at video frequencies or at D.-C. plus video shown in FIG. 3 of the drawing.

In a radar system it is conventional to use either a single antenna for transmission and reception or a separate transmitter antenna for transmission as in the Page patent. Normally a separate transmitter antenna if so used is more of a "searchlight" arrangement because the angular sensitivity normally attainable from a single lobe is far removed from that attainable with lobe comparison techniques as applied to the receiver, typically in the Page patent. Thus the receiver apparatus of the radar system is capable of operating as a highly accurate radio direction finder, to locate a remote signal source, even without a local transmitter. Since the provision of angular sensitivity or reception is the primary concern of the present invention, the present discussion will be directed primarily to the receiver operation, it being understood that as such it is primarily a radio direction finder but could be very easily used with a local transmitter and suitable duplexing apparatus and a suitable indicator to provide a complete radar system.

Basically the apparatus in FIG. 1 is a single horn having a large open end 10 of suitable proportions for use in any of a number of different overall arrangements in the typically direct space coupling of the end 10, or indirect coupling by means of some secondary device such as a parabola or lens. Dimensions of the open end 10, as well as the flare rate thereto, would normally be selected in accordance with well known principles to optimize beam width either as a direct radiator or as an indirect radiator to some lens or reflector, whatever the choice may be. H-plane and E-plane vectors are shown to correlate the system with horizontally polarized energy, either for emission or reception.

The large flared portion of the feed system provides a transition from the required dimensions at the open end 10 to a smaller cross sectional area at the apex of the flared section at which point a waveguide 11 is connected. Normally, at least in experimental models, a flanged arrangement 11-a is provided between the horn and waveguide 11. The waveguide 11 is a square waveguide proportioned so as to be capable of supporting the TE_{2,0} mode in two orthogonal planes. Actually the width of the guide need be only 1.4 times that necessary for the dominant mode to permit the propagation of the 1, 1 modes, however, in general it is more convenient to select readily available square guide to provide TE_{2,0} capabilities in both planes. The length of this square waveguide 11 is chosen for compactness so as to be as small as possible, consistent with the requirements for establishing field uniformity therein. A first requirement is provision for the connection of two smaller waveguides 12 and 13 on opposing sides of the waveguide 11 in the

E-plane, the two waveguides 12 and 13 being rectangular waveguides of dominant mode width, namely, that suitable for the propagation of the $TE_{1,0}$ mode. The waveguides 12 and 13 are placed with the large transverse dimension parallel to a plane perpendicular to the longitudinal axis of the waveguide 11. Each of the waveguides 12 and 13 is terminated by a short circuiting plate 14 and 15 which is preceded along the length of the guides 12 and 13 by individual crystal detectors 16 and 17, only detector 17 being indicated for waveguide 13, FIG. 1, it being understood that detector 16 is similarly located in waveguide 12 but hidden from view in the particular showing of FIG. 1 by the portion of the overall apparatus yet to be described. The disposition of the detectors 16 and 17 within the waveguides 12 and 13 is normally preferred for compactness, however in accordance with conventional practice, it may be desirable to place probes in the waveguides and locate the detectors more remotely.

Regardless of their location, the detectors 16 and 17 convert the radio frequency signals at each waveguide into signals of some lower frequency such as a video frequency with a D.-C. component or an intermediate frequency signal if the detectors are also provided with local oscillator signals. The type of incoming signal is, of course, subject to considerable variation which either is, or is not, at least partly within the control of the operator at the location of the receiving antenna of FIG. 1, depending upon whether the receiving antenna is also accompanied by some suitable source of radio frequency energy. For a discussion of a typical arrangement it may be helpful for the moment to consider that the incoming signal is a microwave radio frequency signal which is amplitude modulated with a sinusoidal signal generated and directed toward a distant energy reflective object by suitable apparatus operating in conjunction with the system of FIG. 1, the energy having its E-plane as shown in FIG. 1.

Thus, it is readily seen that with such characteristics of the incoming signal the output at the detectors 16 and 17 will be a signal of a D.-C. nature containing the modulation placed upon the transmitter signal.

Incoming signals thus picked up at horn end 10 when propagated through the horn to the square waveguide 11 exist in the square waveguide 11 as $TE_{1,0}$ and higher mode signals. If the plane of the wavefront of the signal applied to the opening of horn 10 is parallel to the plane of the end 10, the phasing of the signals is substantially uniform across the opening and a basic $TE_{1,0}$ mode signal is excited which finds its way into the waveguide, polarized basically with the E-field in the horizontal plane. If the impingement of an incoming signal is not with a phase front parallel to end 10, then a phase difference exists across the opening of the horn causing dissymmetry of the E-field and exciting unsymmetrical mode signals in the square waveguide, such as the $TE_{2,0}$, $TE_{1,1}$ and $TM_{1,1}$ modes which can exist only when the E-field is unsymmetrical. If the impingement is nonparallel in the horizontal plane but otherwise direct, $TE_{1,1}$ and $TM_{1,1}$ mode signals are excited in waveguide 11 which produce polarity differences at opposing sides of the waveguide 11, the polarities being reversed for the two sides when the direction of the distant energy return object shifts to the opposite side of the axis of directivity.

The signals of the various modes mentioned thus far actually combine within the waveguide 11, if, in fact, they are ever basically distinct, however, the result is that the $TE_{1,0}$ mode signal is always of continuous polarity across the guide whereas the 1, 1 mode signals are of one polarity on one side of the waveguide and of opposing polarity on the other side of the waveguide. In combination, these modes are additive on one side of the waveguide, and subtractive on the other side. These signals may be correctly looked upon as being equal to the "sum plus difference" signals and the "sum minus difference" sig-

nals discussed in my copending application, Serial No. 132,269, filed August 14, 1961, for Balanced Channel Monopulse System.

Actually, the space pattern for each of the detectors 16 and 17 is similar to a lobe which is, of course, quite familiar in the lobing antenna art, the lobes being skewed relative to each other, with the output from each being equal for an object located along the center of the two lobes, one detector 16 or 17 providing the "sum plus difference" output and the other detector the "sum minus difference" output, as appropriate.

The "sum" signal itself may be analyzed as feeding out of the two ports in the walls of the square waveguide 11 with an out-of-phase relationship whereas the "difference" signal feeds out of these ports in-phase. It is important that the phase relationship of the sum and difference signals be adjusted relative to each other so that the "sum" and "difference" signals are exactly in-phase at one of the ports and exactly 180° out of phase at the other, for obtaining maximum sensitivity to the direction of arrival of the energy.

Typical dimensions in a situation intended for operation at 8,800 megacycles per second involve interior dimensions of the square waveguide 11 of 1.80 inches and an axial length of waveguide 11 of 0.75 inch, the axial spacing of the center plane of the waveguides 12 and 13 from the juncture of the square waveguide 11 and the horn 10 being 0.37 inch. This locates the position of the subsequently to be described tapered waveguide 19 which reflects the $TE_{1,1}$ and $TM_{1,1}$ waves in the optimum position for coupling the 1,1 modes to waveguides 12 and 13.

With the apparatus thus far described it is noted that "sum plus difference" signals and "sum minus difference" signals can be derived for distant energy return objects which are displaced in a horizontal plane relative to the axis of directivity of the horn assembly. To provide detection sensitivity for displacement of distant energy return objects from the axis of directivity in the vertical plane, the additional structure of the apparatus of FIG. 1 is required. This apparatus places a one plane (width of E-plane) dimension reduction in the waveguide so that the resultant rectangular waveguide 18 is of double dominant mode width in only the vertical direction or the H-plane, but is of insufficient extent in the horizontal plane to support propagation in that plane of even the $TE_{1,0}$ mode. The result is that the $TE_{1,0}$ and $TE_{2,0}$ modes excited in the square waveguide 11 propagate through the transition or tapered waveguide 19 to the rectangular waveguide 18, to the exclusion of the original $TE_{1,1}$ and $TM_{1,1}$ modes, where they exist as a $TE_{1,0}$ mode signal in waveguide 18 for objects located directly on the axis of directivity in the vertical plane, together with a $TE_{2,0}$ mode signal depending upon the amount and direction of displacement of the distant energy return object relative to the axis of directivity in the vertical plane. The waveguide 18 is suitably short circuit terminated by a transverse conductive wall 18-a.

Actually the $TE_{1,0}$ mode and the $TE_{2,0}$ mode are merely components of an overall combination signal, the result being that the two components are additive in one-half of the rectangular waveguide 18 whereas they are subtractive in the other half.

With the placement of suitable detectors in the upper and lower half of the rectangular waveguide 18 it is possible to independently derive two signals relative to vertical errors, one being equal to the "sum plus difference" signal, the other equal to the "sum minus difference" signal. Again these signals correspond to similarly identified signals contained in my copending application Serial No. 132,269, filed August 14, 1961, for Balanced Channel Monopulse System.

The two detectors mentioned are identified by reference characters 20 and 21 which are independently operative to provide, in accordance with the foregoing discussion, D.-C. type envelope signals representative of the modu-

lation contained upon the incoming radio frequency energy.

As with the "sum" and "difference" signals for the horizontal plane as derived by the waveguides 12 and 13 at the ports of the square waveguide 11, it is also necessary to realize that the phase relationship of the "sum" and "difference" signals is critical at the detectors 20 and 21. Again it is necessary to make certain that the "sum" and "difference" signals are exactly in-phase on one side for one detector (20) and exactly out-of-phase (by 180°) for the other detector (21) or vice versa.

These phase adjustments, as well as those mentioned previously, cause some complexity in understanding because each means for adjustment affects the phase relations of both the $TE_{1,0}$ mode and $TE_{2,0}$ modes in waveguide 11 and of the $TE_{1,0}$ mode and $TE_{2,0}$ mode in waveguide 18. There is also the problem of adjusting the $TE_{1,0}$ mode for equal energy division between waveguide 18 and waveguides 12 and 13. Several techniques which can be used in various combinations to affect the relative amplitudes and phases are: (1) A metal septum 23 typically can be located in the center of waveguide 18 parallel to the narrow dimension, (2) The shape of the leading edge of septum 23 can have a quarter wavelength step of selected width or an adjustable probe can be inserted a quarter wavelength ahead of a non-stepped septum 23 to adjust the amount and phase of the $TE_{1,0}$ energy reflected back to guides 12 and 13; (3) As a further alternate a dielectric slab 24 can be inserted with variable depth to adjust phase of the $TE_{1,0}$ mode; reflected to detectors 20 and 21; and (4) A variation in length of waveguides 11 and 18 is effective to make use of the different propagation velocities of each mode in a given waveguide size.

The use of variable length of waveguide is normally not desired or used except for minor phase adjustments since the minimum lengths, as in the example given here, are preferable for both compactness and maintaining broadband operation. The initial adjustment should be for equal division of $TE_{1,0}$ mode energy to detector pair 16 and 17 and detector pair 20 and 21 which can be measured as the sum of the output of each pair. Typically this can be accomplished by inserting a septum 23 to some arbitrary depth such that the leading edge is close behind the end of the tapered waveguide 19 and adjusting the width of the quarter wave step. The next adjustment is for the phase of the $TE_{1,0}$ mode at waveguides 12 and 13 with respect to the $1,1$ modes. With a fixed angle error in the horizontal of E-plane the error signal is measured and the insertion depth of the septum 23 adjusted for a peak error voltage from the detectors 16, 17. This will have some interaction on the energy division of the $TE_{1,0}$ mode and both adjustments must be repeated possibly two or three times to approach the desired phase and amplitude relation.

The next adjustment is to insert a thin dielectric slab 24 of polystyrene, for example, to adjust the relative phase of the $TE_{1,0}$ mode and the $TE_{2,0}$ mode at detectors 20 and 21. A fixed angle error is introduced in the vertical or H-plane and the error voltage, which is the difference of the outputs of detectors 20 and 21, is peaked up as a function of the depth of the dielectric. This operation will change the setting for peak error voltage at detectors 16 and 17 and will require repeating, two or three times, this adjustment and adjustment of septum 23 insertion depth to approach the desired peaking of error signal at both detector pairs. As long as the error signal at detector pairs 16 and 17 is peaked even through the combination of the above two adjustments, the energy split of the $TE_{1,0}$ mode will remain correct. Also the dielectric slab 24 and the septum 23 will have negligible effect on the $TE_{2,0}$ mode because they have an E-field null in their vicinity.

It should be emphasized that these adjustments are simply to peak up sensitivity of the angle error signal

while the boresight or electrical accuracy of the null portions is essentially dependent on symmetry of the antenna. Thus, symmetry is critical and the adjustments and dimensions of the device are not critical. The antenna can operate quite satisfactorily at 10° or 20° phase errors with only a minor loss of sensitivity. Many other variations of these adjustments could be used; however, the above technique can be used satisfactorily.

Further typical dimensions are as follows:

10 Waveguide 18:

Height ----- 1.8 inches.

Width ----- 0.4 inch for convenience of using standard crystals. Width has little effect on operation.

15 Length ----- The length of the guide to the rear of the septum has little effect on its operation. A length of 1.65" extent behind the septum is convenient and satisfactory.

20 Septum ----- With a solid metal septum flush to the rear of tapered waveguide 19 satisfactory phase relations are obtained without the use of the dielectric. A dielectric can be inserted in front of this point for adjustment if needed.

In further elaboration of the exact structure of the foregoing device the essential proportions of the transition device 19 are as follows:

The tapered portion of waveguide 19 is symmetrical about the axis of the horn and tapers in the plane only. The vertical dimension is 1.8" inside non-tapering and the horizontal dimension tapers from 1.8" inside, the width of the square waveguide 11, down to 0.4" inside, the width of rectangular waveguide 18. The taper is accomplished over a length along the horn axis of 1.25".

Most of the dimensions are not critical, but symmetry is of major importance for maintaining good boresight (null position) as a function of frequency.

Utilization of the "sum plus difference" signals and the "sum minus difference" signals produced by the apparatus of FIG. 1 indicative of the direction of a distant energy return object relative to the axis of directivity of the antenna system is typified by the apparatus indicated schematically in FIG. 2. It is to be emphasized that this is a typical sub-combination intended to illustrate the utilization of the "sum plus difference" and "sum minus difference" signals and is not necessarily limiting so far as the basic feed system of FIG. 1 itself. For simplicity the apparatus of FIG. 2 is shown with the signals derived by the detectors 16-17 and 20-21 coming from two separate horns. Actually this is merely a simplified presentation, it being understood that the detectors correspond identically to those of similar reference characters in the apparatus of FIG. 1. This form of presentation is acceptable because of the fact that the various signals which exist in the feed structure of FIG. 1, although they all combine to produce various relationships of the $TE_{1,0}$, $TE_{1,1}$, $TM_{1,1}$, and $TE_{2,0}$ modes in the feed system, can be analyzed in terms of their components in the separate orthogonal planes.

The outputs of the detectors 16 and 17 are applied across potentiometer 25 to a variable gain amplifier 26. The signal at this point can be in a number of different forms, depending upon the nature of the distant signal source, however, it can be borne in mind that a typical operating situation was previously set forth wherein the incoming signal was an amplitude modulated radio frequency signal. Thus, the resultant signals applied to the opposite ends of the potentiometer 25 will basically have a variational component at the frequency of the modulation on the radio frequency signal. If the antenna axis of directivity is pointed directly toward a distant energy return object, such pointing is indicated by

the fact that the "difference" signal is zero. In other words, the outputs from the detectors 16 and 17, because of the reverse polarity connection of the two detectors as shown, will be of equal amplitude and opposite polarity. Under these conditions cancellation occurs at the midpoint of potentiometer 25, which is normally the signal point which is selected for connection to the variable gain amplifier 26, and the variable gain amplifier 26 does not receive any signals.

A second variable gain amplifier 27 is similarly connected by means of a centrally adjusted tap on potentiometer 28 to the detectors 20 and 21 which correspond to the similarly referenced detectors of FIG. 1 for the elevation plane sensing signals. Again, as with the horizontal plane, the outputs of the oppositely poled detectors 20 and 21 will be equal in amplitude and opposite in polarity when the distant energy return object is located on the axis of directivity in the elevation plane.

With the apparatus thus far described and the canceling aspect of the inputs to the variable gain amplifiers 26 and 27 it is apparent that the outputs of these variable gain amplifiers become virtually nonexistent when the antenna axis of directivity is pointed directly on the distant energy return object or signal source. Although absence of signal in these outputs indicates direct antenna alignment if there is a signal present, to sense the presence of a signal and perform other functions dependent on a measure of signal strength, a third amplifier channel, namely that of amplifier 29, is coupled to the outputs of the detectors 16, 17, 20, and 21 by means of a transformer 30. The coupling of the transformer 30 is such that the signals from the detectors are not subtractive as with the signals applied through the potentiometers 25 and 28 to amplifiers 26 and 27, but rather, are additive in their application to the variable gain amplifier 29. Thus, the variable gain amplifier provides an output proportional to the sum of the outputs of the detectors 16, 17, 20, and 21.

With sinusoidal amplitude modulation on the incoming signal it is then apparent that the phasing of the signal applied to the variable gain amplifier 26 will vary relative to the signal applied to the variable gain amplifier 27 being either substantially in phase with it or substantially out of phase with it so far as the sinusoidal modulation is concerned. This phase relationship makes it possible for the output of the variable gain amplifier 26 to be employed to control a servo system 31 which can be utilized to operate mechanical drive 32 for orienting the antenna of FIG. 1 to achieve correspondence between the antenna axis of directivity and the direction of the distant energy source. This control could typically be exercised in any of several ways, being, for example, in the form of a conventional antenna positioning device such as that employed for radar installations on surface ships or on land or could be some form of vehicle direction orientation of travel guidance through reactive forces as by rudder positioning for aircraft or missiles whereby the entire aircraft or missile structure is caused to orient itself in the direction of the distant energy return object. It may also be a combination of both as used in some guided missile applications.

As to the guidance manipulations for two planes, the signal from the variable gain amplifier 27 can be employed to provide guidance orientation control in the elevation plane through a second suitable servo system 33, acting through a suitable mechanical drive 34 to cause the desired change in orientation of the antenna of FIG. 1.

The amplifiers 26, 27, and 29 have been referred to as variable gain amplifiers. Actually, these can be amplifiers of any nature suitable for the frequencies and amplitudes of signals involved. The variable gain characteristics are desired because of the extremely wide variation in signal amplitude experienced in a typical application of a system of this type such as in homing upon an enemy radar installation where the signal strength variation is extremely great between the initial or "acquisition" conditions and the final "terminal" conditions immediately pre-

ceding impact. Thus it is desired to utilize the output of the variable gain amplifier 29 to control the amplification of all of the variable gain amplifiers so that as the output of the variable gain amplifier 29 increases in amplitude the overall gain of all amplifiers is reduced so that extremely large amplitude output signals to the servo systems 31 and 33 are avoided, which otherwise might cause excessive hunting and erratic control. Thus the output from variable gain amplifier 29 will normally contain a detector and low pass filter 35 which is employed to derive a D-C. signal dependent in magnitude upon the amplitude of the output from the variable gain amplifier 29 which D-C. signal is supplied in conventional A.G.C. or A.V.C. manner with appropriate polarity to control the gain of the variable gain amplifiers 26, 27, and 29.

It thus becomes apparent that these variable gain amplifiers are typically similar in general configuration to the variable gain amplifiers used in the intermediate frequency and the radio frequency stages of radio receivers, it being understood, of course, that loading and coupling circuits involved must be appropriate for the particular form and frequency of signals encountered, such, of course, being quite obvious to those skilled in the art.

The apparatus thus far described in connection with FIG. 2, as applied to FIG. 1, is complete in itself, and entirely capable of highly desirable operation in the control of missile flight. The form of signal input involved has been described as being sinusoidally modulated radio frequency energy. This form of energy, is, of course, readily available if the complete system of FIGS. 1 and 2 is accompanied by a local source of radio frequency energy which can be modulated as desired to provide the desired form of illumination of distant energy return objects. Since it is quite likely that guidance may be desired in some instances for missiles which do not carry their own source of radio frequency illumination of a distant object, and since a typical enemy vehicle would normally contain its own radar system, it is desired that the system of FIGS. 1 and 2 be operable with energy received from the enemy radar installation itself. The only difficulty is that the apparatus as thus far described was specifically described in connection with sinusoidally modulated signals and it is, of course, quite unlikely that an enemy radar system would obligingly emit sinusoidal modulation of a continuous wave carrier signal and keep it pointed in the direction of the missile to facilitate its own destruction. Thus it is desired that the apparatus of FIG. 2 be extended somewhat beyond the preceding basic discussion to enable it to operate effectively with the normal pulse type radar signals.

The addition of pulse stretchers and low pass filters in components 36, 37, and 38, connected respectively between the variable gain amplifier 26 and its servo 31, between the variable gain amplifier 29 and detector and filter 35, and between the variable gain amplifier 27 and its servo system 33, provides the desired capabilities to permit operation on short duration pulses. Basically the operation is substantially the same as that previously described, the pulse stretchers normally being, of course, well known prior art devices wherein a storage element of some sort such as a condenser is charged rapidly through a small resistance during the pulses and discharged slowly through a large resistance after each pulse to provide an apparent "stretching" of the applied pulses and the low pass filters being obvious from their name to provide for reduction in the harmonic content of the stretched pulses.

The apparatus of the foregoing FIGURES 1 and 2 is subject to further variation or refinement to enhance the utility thereof in the presence of other conditions normally met by missile systems homing on enemy radar installations. Normally, such missiles will have initial guidance controlled from the launch site, or will fly initially in some ballistic or inertial guidance manner which will give way to a terminal guidance system such as that of the present invention. Usually it is desired that the

terminal guidance be inoperative until such time as it is clear that a sufficiently strong signal is being received from the enemy radar installation so as to insure that the missile selects that particular source of radiation for terminal guidance operation.

In view of the foregoing, a threshold control 39 is provided which blocks the servo systems 31 and 33 until such time as a selected amplitude at the output of the variable gain amplifier 29 is realized. This situation changes upon the attainment of a sufficiently large output from the variable gain amplifier 29 to operate the threshold control 39 which will unblock the servo systems 31 and 33 for terminal guidance.

In other situations wherein the device of the present invention can find application, direction sensing of a distant source of a substantially continuous wave or unmodulated nature may be desired.

The presence of the coupling transformer 30 in the apparatus of FIG. 2, together with the normal forms of coupling circuits used in variable gain amplifiers and servos 31 and 33 are not normally such as would respond to continuous wave signals. To this end, the apparatus configuration of FIG. 3 has desirable properties. This device is substantially the same as that of the previously described FIG. 2 having corresponding components identified by like reference characters, however, it is arranged throughout so as to give it the "D.-C." response necessary to operate with continuous wave signals. Thus, the components 16, 17, 20, 21, 25, and 28 correspond to those of the same numbers in FIG. 2. The apparatus of FIG. 3 involves "D.-C." amplifiers 50 and 51 instead of the variable gain amplifiers 26 and 27 and push-pull "D.-C." amplifiers 52, 53, and adder 54 are employed in place of the coupling transformer 30 and the variable gain amplifier 29 of FIG. 2. The apparatus of FIG. 3 involves "D.-C." servo systems 55 and 56, together with mechanical drives 57 and 58, which drives may or may not be similar to 32 and 34 of FIG. 2, depending on the particular desires of the designer, since the particular configuration chosen at this point is not unique in the practice of the invention.

In general, the filter 59 corresponds to the detector and filter 35 of FIG. 2 and the threshold control 60 corresponds to the threshold control 39 of FIG. 2. AGC operation is substantially the same as that described in connection with FIG. 2, as is the threshold arrangement on the blocking of servo systems 55, 56, which permits initial guidance of some ballistic or inertial nature, followed by terminal guidance with the apparatus of FIG. 3 in conjunction with that of FIG. 1.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. In a direction sensitive antenna system, a first waveguide capable of propagating the $TE_{2,0}$ mode in one plane therein and the $TE_{1,1}$ and $TM_{1,1}$ modes, first and second means for coupling to $TE_{1,0}$, $TE_{1,1}$, and $TM_{1,1}$ mode energy in said waveguide, the coupling of the first means to the $TE_{1,1}$ and $TM_{1,1}$ modes being opposite relative to the coupling to the $TE_{1,0}$ mode in comparison to the relationship between the coupling of the second means to the $TE_{1,1}$ and $TM_{1,1}$ modes and to the $TE_{1,0}$ mode, a second waveguide capable of supporting the $TE_{2,0}$ mode in one plane therein, transition means connecting said waveguides whereby $TE_{1,0}$ and the $TE_{2,0}$ mode energy of the first waveguide is delivered to the second waveguide, third and fourth means for coupling to $TE_{1,0}$ and $TE_{2,0}$ mode energy in said second waveguide, the coupling of the third means to the $TE_{2,0}$ mode being opposite relative to the coupling to the $TE_{1,0}$ mode in comparison to the relationship between the coupling of the fourth means to the $TE_{2,0}$ mode and to the $TE_{1,0}$ mode, and means for controlling the division of $TE_{1,0}$ mode energy

between the first and second means and the third and fourth means.

2. In a direction sensitive antenna system, a first waveguide capable of propagating the $TE_{2,0}$ mode in one plane therein and the $TE_{1,1}$ and $TM_{1,1}$ modes, first and second ports in said waveguide for coupling to $TE_{1,0}$, $TE_{1,1}$ and $TM_{1,1}$ mode energy in said waveguide, the coupling of a first port to the $TE_{1,1}$ and $TM_{1,1}$ modes being opposite relative to the coupling thereof to the $TE_{1,0}$ mode in comparison to the relationship between the coupling of the second port to the $TE_{1,1}$ and $TM_{1,1}$ modes and to the $TE_{1,0}$ mode, a second waveguide capable of supporting the $TE_{2,0}$ mode in one plane therein, transition means connecting said waveguides whereby $TE_{1,0}$ and the $TE_{2,0}$ mode energy of the first waveguide is delivered to the second waveguide, third and fourth ports in said second waveguide for coupling to $TE_{1,0}$ and $TE_{2,0}$ mode energy in said second waveguide, the coupling of the third port to the $TE_{2,0}$ mode being opposite relative to the coupling thereof to the $TE_{1,0}$ mode in comparison to the relationship between the coupling of the fourth port to the $TE_{2,0}$ mode and to the $TE_{1,0}$ mode, and means for controlling the division of $TE_{1,0}$ mode energy between the first and second ports and the third and fourth ports.

3. In a direction sensitive antenna system, a first waveguide capable of propagating the $TE_{2,0}$ mode in one plane therein and the $TE_{1,1}$ and $TM_{1,1}$ modes, first and second ports in said waveguide for coupling to $TE_{1,0}$, $TE_{1,1}$, and $TM_{1,1}$ mode energy in said waveguide, the coupling of a first port to the $TE_{1,1}$ and $TM_{1,1}$ modes being opposite relative to the coupling thereof to the $TE_{1,0}$ mode in comparison to the relationship between the coupling of the second port to the $TE_{1,1}$ and $TM_{1,1}$ modes and to the $TE_{1,0}$ mode, a second waveguide capable of supporting the $TE_{2,0}$ mode in one plane therein, transition means connecting said waveguides whereby $TE_{1,0}$ and the $TE_{2,0}$ mode energy of the first waveguide is delivered to the second waveguide, third and fourth ports in said second waveguide for coupling to $TE_{1,0}$ and $TE_{2,0}$ mode energy in said second waveguide, the coupling of the third port to the $TE_{2,0}$ mode being opposite relative to the coupling thereof to the $TE_{1,0}$ mode in comparison to the relationship between the coupling of the fourth port to the $TE_{2,0}$ mode and to the $TE_{1,0}$ mode, means for controlling the division of $TE_{1,0}$ mode energy between the first and second ports and the third and fourth ports, signal conversion means connected to each port for deriving an output signal in dependency on the amplitude of the radio frequency envelope of signals coupled out of the ports, means for combining in polarity opposition the converted output signals from the conversion means for the first and second ports, and means for combining in polarity opposition the converted output signals from the conversion means for the third and fourth ports.

4. In a direction sensitive antenna system, a first waveguide capable of propagating the $TE_{2,0}$ mode in one plane therein and the $TE_{1,1}$ and $TM_{1,1}$ modes, first and second ports in said waveguide for coupling to $TE_{1,0}$, $TE_{1,1}$, and $TM_{1,1}$ mode energy in said waveguide, the coupling of a first port to the $TE_{1,1}$ and $TM_{1,1}$ modes being opposite relative to the coupling thereof to the $TE_{1,0}$ mode in comparison to the relationship between the coupling of the second port to the $TE_{1,1}$ and $TM_{1,1}$ modes and to the $TE_{1,0}$ mode, a second waveguide capable of supporting the $TE_{2,0}$ mode in one plane therein, transition means connecting said waveguides whereby $TE_{1,0}$ and the $TE_{2,0}$ mode energy of the first waveguide is delivered to the second waveguide, third and fourth ports in said second waveguide for coupling to $TE_{1,0}$ and $TE_{2,0}$ mode energy in said second waveguide, the coupling of the third port to the $TE_{2,0}$ mode being opposite relative to the coupling thereof to the $TE_{1,0}$ mode in comparison to the relationship between the coupling of the fourth port to the $TE_{2,0}$ mode and to the $TE_{1,0}$ mode, means for controlling the division of $TE_{1,0}$ mode energy between the first and second ports and the third and fourth ports, sig-

nal conversion means connected to each port for deriving an output signal in dependency on the amplitude of the radio frequency envelope of signals coupled out of the ports, means for combining in polarity opposition the converted output signals from the conversion means for the first and second ports, means for combining in polarity opposition the converted output signals from the conversion means for the third and fourth ports, and means combining in additive polarity the combined output signals from the conversion means for all the ports.

5. In a direction sensitive antenna system, a first waveguide capable of propagating the $TE_{2,0}$ mode in one plane therein and the $TE_{1,1}$ and $TM_{1,1}$ modes, first and second ports in said waveguide for coupling to $TE_{1,0}$, $TE_{1,1}$, and $TM_{1,1}$ mode energy in said waveguide, the coupling of a first port to the $TE_{1,1}$ and $TM_{1,1}$ modes being opposite relative to the coupling thereof to the $TE_{1,0}$ mode in comparison to the relationship between the coupling of the second port to the $TE_{1,1}$ and $TM_{1,1}$ modes and to the $TE_{1,0}$ mode, a second waveguide capable of supporting the $TE_{2,0}$ mode in one plane therein, said waveguide being open at one end and short circuit terminated at the other end, transition means connecting the open end of said second waveguide to the first waveguide whereby $TE_{1,0}$ and the $TE_{2,0}$ mode energy of the first waveguide is delivered to the second waveguide and $TE_{1,1}$ and $TM_{1,1}$ energy is reflected back into the first waveguide for delivery to the first and second ports, third and fourth ports in said second waveguide disposed between the open end and the short circuit termination for coupling to $TE_{1,0}$ and $TE_{2,0}$ mode energy in said second waveguide, the coupling of the third port to the $TE_{2,0}$ mode being opposite relative to the coupling thereof to the $TE_{1,0}$ mode in comparison to the relationship between the coupling of the fourth port to the $TE_{2,0}$ mode and to the $TE_{1,0}$ mode, and means disposed in said second waveguide for controlling the division of $TE_{1,0}$ mode energy between the first and second ports and the third and fourth ports.

6. In a direction sensitive antenna system, a first waveguide capable of propagating the $TE_{2,0}$ mode in one plane therein and the $TE_{1,1}$ and $TM_{1,1}$ modes, first and second ports in said waveguide for coupling to $TE_{1,0}$, $TE_{1,1}$, and $TM_{1,1}$ mode energy in said waveguide, the coupling of a first port to the $TE_{1,1}$ and $TM_{1,1}$ modes being opposite relative to the coupling thereof to the $TE_{1,0}$ mode in comparison to the relationship between the coupling of the second port to the $TE_{1,1}$ and $TM_{1,1}$ modes and to the $TE_{1,0}$ mode, a second waveguide capable of supporting the $TE_{2,0}$ mode in one plane therein, said waveguide being open at one end and short circuit terminated at the other end, transition means connecting the open end of said second waveguide to the first waveguide whereby $TE_{1,0}$ and the $TE_{2,0}$ mode energy of the first waveguide is de-

livered to the second waveguide and $TE_{1,1}$ and $TM_{1,1}$ energy is reflected back into the first waveguide for delivery to the first and second ports, third and fourth ports in said second waveguide disposed between the open end and the short circuit termination for coupling to $TE_{1,0}$ and $TE_{2,0}$ mode energy in said second waveguide, the coupling of the third port to the $TE_{2,0}$ mode being opposite relative to the coupling thereof to the $TE_{1,0}$ mode in comparison to the relationship between the coupling of the fourth port to the $TE_{2,0}$ mode and to the $TE_{1,0}$ mode, and means disposed in said second waveguide for controlling the division of $TE_{1,0}$ mode energy between the first and second ports and the third and fourth ports and the phasing of the energy reflected by the short circuit termination.

7. In a direction sensitive antenna system, a first waveguide capable of propagating the $TE_{2,0}$ mode in one plane therein and the $TE_{1,1}$ and $TM_{1,1}$ modes, first and second ports in said waveguide for coupling to $TE_{1,0}$, $TE_{1,1}$, and $TM_{1,1}$ mode energy in said waveguide, the coupling of a first port to the $TE_{1,1}$ and $TM_{1,1}$ modes being opposite relative to the coupling thereof to the $TE_{1,0}$ mode in comparison to the relationship between the coupling of the second port to the $TE_{1,1}$ and $TM_{1,1}$ modes and to the $TE_{1,0}$ mode, a second waveguide capable of supporting the $TE_{2,0}$ mode in one plane therein, said waveguide being open at one end and short circuit terminated at the other end, transition means connecting the open end of said second waveguide to the first waveguide whereby $TE_{1,0}$ and the $TE_{2,0}$ mode energy of the first waveguide is delivered to the second waveguide and $TE_{1,1}$ and $TM_{1,1}$ energy is reflected back into the first waveguide for delivery to the first and second ports, third and fourth ports in said second waveguide disposed between the open end and the short circuit termination for coupling to $TE_{1,0}$ and $TE_{2,0}$ mode energy in said second waveguide, the coupling of the third port to the $TE_{2,0}$ mode being opposite relative to the coupling thereof to the $TE_{1,0}$ mode in comparison to the relationship between the coupling of the fourth port to the $TE_{2,0}$ mode and to the $TE_{1,0}$ mode, means disposed in said second waveguide between the third and fourth ports and the short circuit termination for providing phase adjustment between the $TE_{1,0}$ mode energy reflected and the $TE_{2,0}$ mode energy reflected, and means disposed in said second waveguide for controlling the division of $TE_{1,0}$ mode energy between the first and second ports and the third and fourth ports.

No references cited.

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