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R. H. DICKE

2,830,288

LOBING SYSTEM

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2 Sheets-Sheet 1

FIG.1

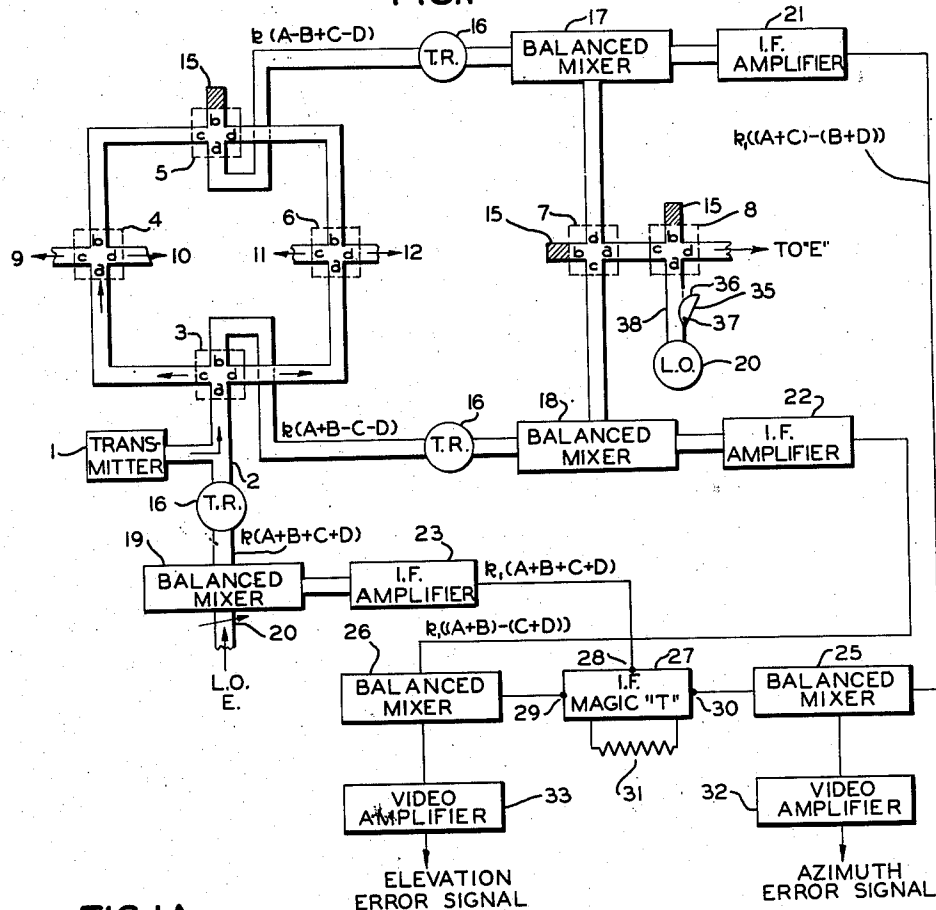


FIG. 1A

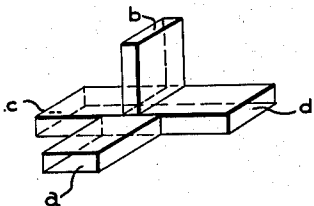


FIG. 2

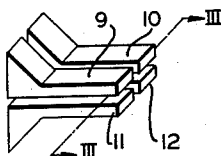


FIG. 3

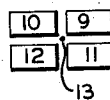


FIG.3A

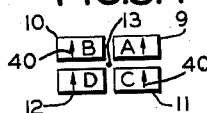


FIG. 3B

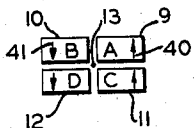


FIG.3C

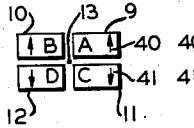
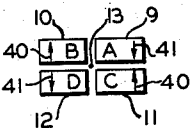


FIG.3D



INVENTOR
ROBERT H. DICKE

BY

ATTORNEY

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2,830,288

LOBING SYSTEM

Robert H. Dicke, Cambridge, Mass., assignor, by mesne assignments, to the United States of America as represented by the Secretary of the Navy

Application October 5, 1945, Serial No. 620,612

13 Claims. (Cl. 343—16)

My present invention relates to directional radio antennas and in particular to such antennas that yield information that aids in maintaining the true direction of the antenna, as for keeping the antenna pointed at a desired transmitter or target.

In radio communication between two directive radio stations or in radar systems, it is often desirable to have an antenna system which is directional and which further has means for indicating when the antenna is pointed directly at the other station or at the desired target. Such systems as have been used in the past have involved mechanical lobe-switching or systematic antenna scanning, such as conical scanning or other types of beam scanning. All of these past systems are characterized by a necessity for moving mechanical parts, such as rotating antenna configurations or rotating capacitor devices, and associated motors.

It is a specific object of my present invention to provide a directive radio antenna which will perform the function of a lobe switched or conical scanning or other type of directional antenna of the character being discussed without the use of any moving parts. Accordingly, my present invention contemplates a radio system which may be either a receiver system or a radar system as desired, having an antenna system comprising a plurality of antenna elements which may be so fed that together these elements produce a single directive beam for transmitting. In receiving, the signals received by the aforementioned individual antenna elements are separated and then recombined in a novel fashion to produce directional error signals in at least two planes, such as, for example, vertical and horizontal planes, as well as a reference signal from the main beam. These signals are then further combined to produce direct current directional error impulses which may be used to actuate visual directional error devices or automatic directional error corrective devices.

It is another object of my invention to provide such a directive radio system that will eliminate spurious signals that tend to provide false error signals.

It is a still further object of my invention to provide such a system in which the local oscillator of the detector for generating the error signal is operative only when a received signal is in the antenna system.

It is another object of my invention to provide a directive biplanar simultaneous lobe comparison antenna system which will provide both azimuth and elevation error signals without the use of any moving part.

It is a still further object of my invention to provide a directive biplanar simultaneous lobe comparison antenna system for a radar system which may be used for both transmitting and receiving and will provide both azimuth and elevation error signals without the use of any moving parts.

These and other objects of my invention may be more fully understood from a careful consideration of the following detailed description when taken together with the

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accompanying drawings, the figures of which illustrate typical embodiments of this invention.

In the drawings:

Fig. 1 illustrates an embodiment of my invention in electrical schematic form as embodied in a radar system;

Fig. 1A illustrates one type of duplex balancer that may be used in the apparatus of Fig. 1;

Fig. 2 illustrates an arrangement of antenna elements that may be used with the apparatus of Fig. 1;

Fig. 3 is a cross section along the line III—III in Fig. 2; Figs. 3A to 3D inclusive illustrate various conditions of electrical phasing that may exist in the antennas of Fig. 2 when those antennas are receiving radio signals;

Fig. 4 illustrates the character of the transmission beam produced by the antenna of Fig. 2;

Fig. 5 illustrates a second embodiment of my invention in electrical schematic form;

Fig. 6 illustrates an arrangement of antenna elements that may be used with the apparatus of Fig. 5;

Fig. 7 is a cross section taken along the line VII—VII in Fig. 6; and

Figs. 7A to 7D inclusive illustrate the various electrical phase configurations that may exist in the antennas of Fig. 6 when these antennas are receiving radio signals.

Although my invention may be illustrated more simply in a radio receiving system, the apparatus of Fig. 1 shows the invention as embodied in a radar system, inasmuch as the function of receiving is included in such systems. Accordingly, a radio transmitter 1 is provided connected to a transmission line 2. The energy generated by the transmitter 1 is led through the transmission line 2 to a first junction of four transmission lines *a*, *b*, *c*, and *d*, known as a "duplex balancer," illustrated schematically in a block 3. For a better understanding of the invention, the "duplex balancer" will be now explained in greater detail.

The blocks 3, 4, 5, 6, 7 and 8 inclusive each illustrate a "duplex balancer," disclosed and so-named in the copending application of Warren A. Tyrrell for "Coupling Arrangements for Use in Wave Transmission Systems," Serial No. 470,810, filed December 31, 1942, now Patent No. 2,445,895, dated July 27, 1948, and assigned to Bell Telephone Laboratories, Inc. The duplex balancer is a system comprising a common junction of four or more transmission lines, *a*, *b*, *c*, and *d*, with each other or with a fifth line. If the system is matched to eliminate resonance in the various lines for the energy being carried therein, the electrical structure and symmetry of the system may be so arranged that the following characteristics are had, among others:

(1) Power fed into line *a* passes into lines *c* and *d* in equal quantities, emerging from *c* and *d* in the same phase, no power passing into line *b*.

(2) Power fed into lines *c* and *d* in phase enters line *a*, but not line *b*.

(3) Power fed into lines *c* and *d* in phase opposition enters line *b*, but not line *a*.

(4) Power fed into line *c* or *d* enters lines *a* and *b* but not the remaining line *d* or *c*.

Such a matched arrangement is more specifically termed a "Magic Tee," and is described in greater detail in my own copending application for "Transmission Systems," Serial No. 581,695, filed March 8, 1945, now Patent No. 2,593,120, dated April 15, 1952, assigned to the United States Government, wherein certain matching means for a Magic Tee constructed of wave guides are disclosed. The above enumerated characteristics are employed in my present invention as will hereinafter be more fully explained.

Although a duplex balancer may be made of any de-

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sired type of transmission line, or of circuit elements, as discussed and shown in the aforementioned copending application of Tyrrell, only that form constructed entirely of wave guides, as for example, that illustrated in Fig. 1A, will be considered herein, inasmuch as the embodiments of my invention herein described illustrate the invention as it may be practiced using wave guides for transmission lines. When any branch a , b , c , or d of any Magic Tee is not being used, that branch should preferably be terminated in an impedance that will avoid reflections of energy therein, such as the characteristic impedance of the branch. Accordingly in Fig. 1, the terminations 15 are preferably characteristic impedances for the branches b of the Magic Tee in which they are installed.

Referring now to Figs. 1 to 4 inclusive, energy entering the first line a of the first Magic Tee 3 will in accordance with the above discussion divide and pass into the third and fourth lines c and d of this Magic Tee in equal quantities and in like phase. No energy will enter the second line b . Thereafter the energy in the third line c will proceed into the first line a of the second Magic Tee 4, and again will divide and leave this second Magic Tee 4 in equal quantities and like phase through the third and fourth lines c and d , respectively, thereof. Likewise, the energy from the fourth line d of the first Magic Tee 3 will enter the first line a of the third Magic Tee 6 and divide and leave that Magic Tee through the third and fourth lines c and d , respectively, thereof in equal quantities and like phase. From the third and fourth line, c and d , respectively, of the second and third Magic Tees 4 and 6 respectively, the energy will then pass to four antenna elements 9, 10, 11 and 12 which are thereunto connected by suitable transmission lines.

These antenna elements 9, 10, 11 and 12 are preferably symmetrically arranged around a point 13 and are fed with equal signals of like phase from the second and third Magic Tees 4 and 6, respectively. As a result, a single lobe 14 of energy is produced by the four antenna elements 9 to 12 inclusive together, this lobe having an axis $Z-Z$ passing through the point 13. From one aspect, the four antenna elements 9 to 12 inclusive comprise two vertically aligned pairs of antennas 9 and 11, and 10 and 12, and from another aspect they comprise two horizontally aligned pairs of antennas 9 and 10, and 11 and 12, respectively. A vertically aligned pair, 9 and 11, is illustrated alone in Fig. 4 to simplify the discussion. Thus for transmission purposes, the energy generated by the transmitter 1 is emitted by the combined antennas 9 to 12 inclusive as a single directive beam 14.

For reception purposes, however, it is convenient to think of the energy in each antenna element 9, 10, 11 and 12 as a separate portion of the received energy and to consider the individual phases of these portions. Each antenna element 9, 10, 11 and 12 receives an individual portion A, B, C, or D respectively of the energy reflected back into the antenna from a target T that may be in the beam 14. The portions received by the antenna elements each have their individual phase with respect to each of the others. Thus, for example, when the target T lies on the axis $Z-Z$, the distances L and L' to each antenna element 9 and 11 respectively are the same, and the portions of energy A and C respectively received in these elements will have the same phase. However, when the target T is at T' the distances M and M' to the antenna elements 9 and 11, respectively, are different, and the portions of energy A and C respectively received in these antennas will have different phases with respect to each other which are resolvable into two pairs of components, having respectively like and opposite phases. Similarly, as will be hereinafter explained in greater detail, an off-axis position of the target T in a horizontal plane will result in oppositely phased pairs of components of the energy in other pairs of antennas.

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The portions of energy A, B, C, and D received by the antenna elements 9, 10, 11 and 12 respectively are returned to the Magic Tees 4 and 6 respectively through the respective third and fourth lines c and d thereof.

Considering now the second Magic Tee 4, for example, the inphase components of the portions A and B of the energy in the third and fourth lines c and d thereof combine in the fashion $A+B$ and enter the first line a thereof, while the oppositely phased components of said portions A and B combine in the fashion $A-B$ and enter the second line b thereof. Likewise, in the third Magic Tee 6, the inphase components of the portions C and D of energy returned to this Magic Tee combine in the fashion $C+D$ and enter the first line a thereof, while the oppositely phased components of said portions C and D combine in the fashion $C-D$ and enter the second line b thereof. Thus in the second lines b of the second and third Magic Tees 4 and 6 respectively, two first parts $A-B$ and $C-D$ of the returned signal will be had, while in the first lines a of these Magic Tees, two second parts $A+B$ and $C+D$ of the returned signal will be had.

The two first parts $A-B$ and $C-D$ of the returned signal are brought to a fourth Magic Tee 5 through the third and fourth line c and d thereof. The inphase components of these two first parts $A-B$ and $C-D$ combine in the first line a of the fourth Magic Tee 5, and provide a first directional error signal $k(A-B+C-D)$, where k is a constant of proportionality. A matching termination 15 is provided for the second line b of the fourth Magic Tee 5, for the purpose of absorbing any signal having the value $k(A-B-(C-D))$, the reason for which will be hereinafter explained.

Returning now to the two second parts $A+B$ and $C+D$ of the returned signal present in the first lines a of the second and third Magic Tees 4 and 6 respectively, these two second parts combine in the first Magic Tee 3, entering therein through the third and fourth line c and d thereof. The inphase components of these two second parts $A+B$ and $C+D$ combine in the first line a to form a directional reference signal $k(A+B+C+D)$, which is the only signal that is had when the target T lies precisely on the axis $Z-Z$. The oppositely phased components of these two second parts $A+B$ and $C+D$ combine and enter the second line b of the first Magic Tee 3 and form a second directional error signal $k(A+B-C-D)$. The first and second directional error signals are in reality azimuth and elevation error signals respectively when the aforementioned pairs of antennas are vertically and horizontally disposed, as will hereinafter become apparent.

The first and second directional error signals and the directional reference signal are each passed through respective receiver protective devices, which may be TR boxes 16, and thence to mixers 17, 18, and 19 respectively, preferably of the balanced mixer type. A common local oscillator 20 is provided for the mixers 17, 18 and 19. The local oscillator output is fed to the first line a of a duplex balancer 8 which is preferably a Magic Tee. In order that essentially line impedance may be presented to the first arm a of the Magic Tee 8 from the local oscillator 20, it is desirable to include a matched non-reflective attenuator, as for example the attenuator 35, in the line 38 from the local oscillator to the said first arm a . The attenuator 35 has a strip of absorptive material 36 on a curved surface, and is hinged at a point 37 in such a manner as to permit insertion of the material 36 into the line 38 in varying degrees as desired. The attenuator 35 and other similar suitable attenuators are more fully described in the copending application of Shepard Roberts, Serial No. 523,885, filed February 25, 1944, now Patent No. 2,646,551, assigned to the United States Government. The signal from the local oscillator divides and inphase equal components enter the third and fourth lines c and d of the duplex balancer 8 in like fashion to similar division in the aforementioned first, second, third and fourth

duplex balancers 3, 4, 5 and 6, respectively. The local oscillator signal in the third branch *c* of the duplex balancer 8 enters the first line *a* of another duplex balancer 7, which again is preferably a Magic Tee, where further equal division takes place and inphase equal portions of the signal proceed into the third and fourth lines *c* and *d* thereof. The signals in these last mentioned lines *c* and *d* are brought into the first and second balanced mixers 17 and 18 as local oscillator signals. Another portion of the local oscillator power, that in the fourth line *d* of the duplex balancer 8 connected to the local oscillator 20 proceeds to the third balanced mixer 19. If, as preferred, the balanced mixers 7 and 8 are each a Magic Tee, then the Magic Tee 8 provides isolation between the Magic Tee 7 and the mixer 19 thereto connected, and the Magic Tee 7 provides isolation between the remaining two mixers 17 and 18. This isolation results from the hereinabove mentioned characteristics of a Magic Tee, which prevent energy entering, for example, the fourth line *d* of either Magic Tee 7 or 8 from passing into the third line *c* thereof, thus preventing cross-signals between the first two mixers 17 and 18 or the Magic Tee 7 and the third mixer 19. Such isolation has the desired result of eliminating a possible source of false error signals. Matching terminations 15 are provided for the second lines *b* of the two last-mentioned duplex balancers 7 and 8, respectively. A line stretcher 20 is provided in the line E between the duplex balancer 8 and the third balanced mixer 19 in order that the proper phase may be had between the two directional error signals and the directional reference signal in operations hereinafter occurring.

In order that the apparatus may be better understood, it is appropriate that the nature of a balanced mixer be discussed briefly. The balanced mixer is a device for accomplishing the usual functions of a mixer with the addition of the following desirable characteristics:

(1) The local oscillator signal alone, even when modulated, does not cause the mixer to produce an output voltage; thus signals such as noise arriving at the mixer with the local oscillator power are not converted.

(2) There must be an input signal to the mixer in addition to local oscillator power before the mixer will produce an output signal.

My copending application for "Electrical Systems," Serial No. 584,226, filed March 22, 1945, now Patent No. 2,547,378, discloses balanced mixer circuits having the above characteristics.

The output from each balanced mixer 17, 18 and 19 is fed to an I. F. amplifier 21, 22 and 23, respectively, in conventional superheterodyne receiver fashion. The output of the first I. F. amplifier 21 is $k_1(A-B+C-D)$, where k_1 is a second constant of proportionality. This is the I. F. of the first directional error signal, and is fed to a fourth balanced mixer 25 for the purpose of detection. The output $k_1(A+B-C-D)$ of the second I. F. amplifier 22, which is now the intermediate frequency of the second directional error signal, is fed to a fifth balanced mixer 26 for the purposes of detection of that signal. The output $k_1(A+B+C+D)$ of the third I. F. amplifier 23 is used in the fashion of a local oscillator voltage for the two last mentioned balanced mixers 25 and 26, and is fed to an electrical circuit 27 which functions preferably in the manner of a matched duplex balancer or Magic Tee. Thus the signal from the last mentioned I. F. amplifier 23 enters the circuit 27 at a first point 28 and is evenly divided and proceeds in like phase out of third and fourth points 29 and 30. From these points 29 and 30, the signals are fed to the fourth and fifth balanced mixers 25 and 26 as the local oscillator signals therefor. No power enters the matching impedance 31. This Magic Tee 27 may be constructed in the fashion of a conventional "hybrid coil" as known in the art of telephony. The textbook "Communication Engineering" by W. L. Everitt (McGraw,

Hill Book Co., second edition 1937) discusses the hybrid coil at page 318. Again, as in the case of the Magic Tees 7 and 8, the Magic Tee 27 provides isolation between the last mentioned balanced mixers 25 and 26. Thus, if, for example, the fourth balanced mixer 25 is not perfectly balanced and feeds some stray signal back into the Magic Tee 27 through its fourth terminal point 30, this signal will be split between the first and second terminal points 28 and 30. Then, because these terminals are further terminated by their characteristic impedances (the third amplifier 23 and the matched impedance 31 being thereto respectively matched to avoid the reflection of energy), this signal is completely absorbed and none is transferred to the third terminal point 29 or the fifth balanced mixer 26.

The directional reference signal $k_1(A+B+C+D)$ from the third I. F. amplifier 23 and the two error signals $k_1(A-B+C-D)$ and $k_1(A+B-C-D)$ from the first and second I. F. amplifiers 21 and 22, respectively, are all of the same frequency, so that the outputs of the last mentioned balanced mixers 25 and 26 will have but one component each, namely a modulated direct current or video pulse. These D. C. signals will each be proportional in magnitude to the respective associated directional error signal, and will be zero when that signal is zero. The video outputs are fed to video amplifiers 32 and 33, respectively, which amplify these video signals and provide first and second directional error signals, respectively, which may be used for visual indication or automatic control devices in manners known to the art.

The operation of the apparatus hereinabove discussed will now be explained in greater detail. Referring to Fig. 4, it will be recalled that when the target *T* is off the axis *Z-Z* the distance from the target *M* and *M'* will be greater for one antenna element 9 than for another 11 in the same plane. This will be true for any pair of antenna elements lying in a plane in which the target is off axis. Thus the portions *A* and *C* of the energy reflected to the antenna elements 9 and 11, for example, will have components having like and different phases upon entering these two antenna elements. As illustrated in Figs. 3A to 3D inclusive, various phase configurations of the reflected energy in the antennas 9 to 12 inclusive may be had for various positions of the target *T* with respect to the axis *Z-Z* of the beam 14. Thus in Fig. 3A, the on-target condition (i. e. target on the axis *Z-Z*) is illustrated, all components of the portions *A*, *B*, *C*, and *D* of reflected energy being in phase, as shown by the arrows 40 in all four antennas 9, 10, 11, and 12. In Fig. 3B, the arrows 40 and 41 illustrate the phase configuration of components of the incoming signals *A*, *B*, *C*, and *D* which is had when there is azimuth error in the target position or in the training of the antenna. This configuration may be represented as $(A+C)-(B+D)$, which is algebraically identical to $A-B+C-D$, and yields the first error signal $k(A-B+C-D)$. In Fig. 3C elevation error is illustrated, as the arrows 40 and 41 show that the top pair 9 and 10 of the antenna elements have components of the portions *A+B* in one phase while the bottom pair 11 and 12 of the antennas have components of the portions *C+D* of reflected energy in the opposite phase. This may be represented as $(A+B)-(C+D)$, which is algebraically identical to $A+B-C-D$ and yields the second error signal $k(A+B-C-D)$. The condition illustrated in Fig. 3D is the condition for an undesired mode of oscillation in the antenna elements, 9 to 12, inclusive. This is a mode combining received signals in the fashion $(A-C)-(B-D)$, which is had by taking the components in phase opposition of the signals $(A-C)$ and $(B-D)$ in the third and fourth lines *c* and *d* of the fourth Magic Tee 5. This undesired signal normally enters the second line *b* of the fourth Magic Tee 5, and is absorbed by the matching termination 15 of that line.

The configurations illustrated in Figs. 3A, 3B and 3C provide the directional reference signal, the azimuth or first error signal and the elevation or second error signal, respectively. As can be readily appreciated, no moving mechanical parts are required to produce these signals.

In Figs. 5, 6, 7, and 7A to 7D inclusive, there is illustrated another embodiment of my invention which, although somewhat simpler than the embodiment of Figs. 1 to 4 inclusive, has similar features. The transmitter 1 feeds into a first duplex balancer 3 through a line 2. The second line *b* of this duplex balancer 3 is terminated in a matching impedance 15 since this line is not used. Equal quantities of energy generated by the transmitter 1 are fed in like phase to the third and fourth arms *c* and *d* of this first duplex balancer 3, and enter the first arms *a* of the second and third duplex balancers 4 and 6, respectively. This power again divides in each of the last mentioned duplex balancers, leaving them in equal quantities and like phase through the third and fourth arms *c* and *d* respectively thereof and passing to four antenna elements 9', 10', 11' and 12', respectively. These antenna elements function in the same manner as the antenna elements 9 to 12 inclusive of the apparatus of Figs. 1 to 4 inclusive, but are somewhat differently arranged. It is this difference in antenna arrangement that make possible the simplified apparatus of Figs. 5 to 7 inclusive. As illustrated in Figs. 6 and 7, two of the antenna elements 9' and 10' are arranged in a horizontal pair on each side of a point in space, 13, while the remaining two antennas 11' and 12' are arranged in a single vertical pair, so that we have now only one horizontal and one vertical pair. The four antennas 9' to 12' inclusive being fed in phase and with equal quantities of energy, a single lobe of energy will be produced on transmission, similar to the lobe 14 of Fig. 4.

From Figs. 7A to 7D inclusive, it is apparent that energy returned from a target on the axis of the antenna system will have only inphase components of the portions A, B, C and D of received energy (Fig. 7A), an azimuth error will yield an oppositely phased set of components of the portions A and B (Fig. 7B), and an elevation error will yield oppositely phased components of the portions C and D (Fig. 7C). Returning energy will again have the inphase component of the portions A, B, C and D thereof added in the first arm *a* of a first duplex balancer 3 to produce a reference signal $k(A+B+C+D)$, which is then passed to a mixer 19 and amplifier 23 to produce a proportionate signal $k_1(A+B+C+D)$. The oppositely phased components of the portions of returned energy A and B present in the horizontal pair of antennas 9' and 10' will leave the second duplex balancer 4 through the second arm *b* thereof, and pass through a mixer 17 and an amplifier 21 to provide a signal $k_1(A-B)$ proportional to the azimuth error. This signal $k_1(A-B)$ is then fed to a balanced mixer 25 as the input signal therefor. Likewise, a signal $k(C-D)$ is provided by the oppositely phased components of the portions of returned energy C and D, which is proportional to the vertical or elevation error. This signal $k(C-D)$ is fed to a mixer 18 and amplifier 22, becoming $k_1(C-D)$, which is then fed into a balanced mixer 26 as the input signal therefor. The reference signal $k_1(A+B+C+D)$ is provided to the balanced mixers 25 and 26 through a junction 27' as a local oscillator signal, similarly to the apparatus of Fig. 1. A common local oscillator 12 feeds through a junction 8' to the first three mixers 17, 18, and 19. The junction 8' may, if desired, be a duplex balancer or Magic Tee rather than a simple junction as illustrated in Fig. 5. Likewise, the junction 27' through which the reference signal $k_1(A+B+C+D)$ is brought to the balanced mixers 25 and 26 may be of the matched "hybrid coil" type of Fig. 1. The outputs of the balanced mixers 25 and 26 are again modulated D. C. or video signals proportional respectively to the azimuth and elevation

errors. Thus it can be seen that the apparatus of Figs. 5 to 7 inclusive functions in a manner similar to the apparatus of Fig. 1, but in a simplified form.

Since certain changes may be made in the above described article and different embodiments of the invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description as shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense. For example, the antenna systems illustrated are only two examples of adaptable systems. A parabolic or other type of reflector could if desired be added and the illustrated antennas might be so located as to illuminate such reflector. If the invention be embodied in an apparatus intended to operate at a frequency too low to permit the economical use of wave guide transmission lines, other types of lines, duplex balancers and antenna elements proper for the operative frequency may be used without departing from the invention. Accordingly it is intended that the invention be limited only as required by the prior art and the spirit of the appended claims.

What is claimed is:

1. A directive radio receiving system comprising, a plurality of individual antennas arranged about a line in space for simultaneously receiving individual portions of the radiation from a particular source thereof, each of said individual portions being resolvable into inphase components and oppositely phased components, said antennas being arranged in a plurality of pairs at least one of which has its members disposed vertically one above and one below said line and at least one other of which has its members disposed horizontally one on each side of said line, means for producing a first signal proportional to the inphase components of all of said portions, means for producing a second signal proportional to the difference between the oppositely phase components of those of said portions received by said vertically disposed pairs of antennas, means for producing a third signal proportional to the difference between the oppositely phased components of those of said portions received by said horizontally disposed pairs of antennas, and means for producing first and second direct current output signals proportional to said second and third signals respectively.

2. Apparatus in accordance with claim 1 in which said direct current producing means comprises, first and second balanced mixers, and means for providing said first signal in like phase and substantially equal quantities to each of said mixers as a local oscillator signal, said second and third signals being brought one to each of said mixers as the input signal therefor, whereby said local oscillator signal is present only when input signals are present in said mixers.

3. An object detecting system comprising, means for generating radio energy, an antenna for directly radiating said energy in a beam and for directly receiving reflected energy from objects in the path of said beam, said antenna comprising four radiating elements arranged symmetrically about the axis of said beam in one or more vertically and one or more horizontally disposed pairs, each of said pairs having its members located on opposite sides of said axis, means for feeding all four of said radiators in the same phase from said generating means, said antenna being thereby adapted to radiate said energy in a single beam, said antenna being further adapted simultaneously to receive a separate portion of said reflected energy in each of said elements, each separate portion being resolvable into an inphase component and an oppositely phased component, means for producing a first signal proportional to the inphase components of all of said portions, means for producing a second signal proportional to the difference between the oppositely phased components of those of said portions received by said vertically disposed pairs of antennas,

means for producing a third signal proportional to the difference between the oppositely phased components of those of said portions received by said horizontally disposed pairs of antennas, and means for producing first and second direct current output signals proportional to said second and third signals respectively.

4. An object detecting system comprising, means for generating radio energy, a first four line duplex balancer connected at its first line to the output of said means in such fashion that said energy divides evenly and proceeds in the same phase into the third and fourth lines and none of said energy enters the second line thereof, second and third similar duplex balancers connected at their respective first lines to said third and fourth lines respectively of said first duplex balancer in like fashion so that said energy proceeds in equal quantities and like phase into the third and fourth lines and none into the second lines thereof, four antennas connected one to each of said third and fourth lines of said second and third duplex balancers, said antennas being symmetrically arranged about a point in space, the two antennas connected to said second duplex balancer being horizontally disposed evenly above said point and the remaining two antennas being horizontally disposed directly below said first two antennas, said antennas forming from one aspect two horizontal pairs and from another aspect two vertical pairs of antennas, said antennas being fed with equal amounts of said energy in like phase and producing a directive beam of said energy having an axis passing through said point, said antennas being each adapted simultaneously to receive individual portions of that amount of said energy that may be reflected to them by an object lying in said beam, and delivering said reflected energy to said second and third duplex balancers through their respective third and fourth lines, the inphase components of said portions present in said third and fourth lines of each of said second and third duplex balancers combining and entering the respective first lines and the oppositely phased components of said portions combining and entering the respective second lines of said second and third duplex balancers to form second and first parts of said reflected energy respectively, a fourth similar duplex balancer connected at its third and fourth lines to said second lines of said second and third duplex balancers respectively, said first parts of said reflected energy present in said second lines of said second and third duplex balancers entering said fourth duplex balancer through said second and third lines thereof and the inphase components of said first parts combining in the first line thereof to form a first directional error signal, the oppositely phased components of said first parts combining and entering the second line of said fourth duplex balancer, a matched termination for said second line, the second parts of said reflected energy entering said first duplex balancer through the third and fourth lines thereof and the oppositely phased components of said second parts combining in the second line of said first duplex balancer to form a second directional error signal, the inphase components of said second parts combining in the first line of said first duplex balancer to form a direction reference signal.

5. An object detecting system comprising, means for generating radio energy, a first four line duplex balancer connected at its first line to the output of said means in such fashion that said energy divides evenly and proceeds in the same phase into the third and fourth lines and none of said energy enters the second line thereof, second and third similar duplex balancers connected at their first lines to said third and fourth lines respectively of said first duplex balancer in like fashion so that said energy proceeds in equal quantities and like phase into the third and fourth lines and none into the second lines thereof, four antennas connected one to each of said third and fourth lines of said second and third duplex balancers, said antennas being symmetrically arranged

about a point in space, the two antennas connected to said second duplex balancer being horizontally disposed one on each side of said point and the remaining two antennas being vertically disposed respectively above and below said point, said antennas being fed with equal amounts of said energy in like phase and producing a directive beam of said energy having an axis passing through said point, said antennas being each adapted to receive individual portions of that amount of said energy that may be reflected to them by an object lying in said beam, and delivering said reflected energy to said second and third duplex balancers through their respective third and fourth lines, the inphase components of said portions present in said third and fourth lines of each of said second and third duplex balancers combining and entering the respective first lines and the oppositely phased components of said portions combining and entering the respective second lines of said second and third duplex balancers, the respective resulting signals present in said last mentioned second lines being first and second directional error signals, the resulting signals due to said reflected energy present in said last mentioned first lines entering said first duplex balancer through its third and fourth lines, the inphase components of said last mentioned signal combining in the first line of said first duplex balancer to form a direction reference signal, and a matched impedance termination for the second line of said first duplex balancer.

6. A directive radio system comprising a transmitter, a first vertically spaced pair of antennas and a second horizontally spaced pair of antennas, a first network coupled to said transmitter for dividing the signal from said transmitter into first and second components which are in phase with each other, second and third networks coupled to said first network, said second network dividing said first component into third and fourth components in phase with each other, said third network dividing said second component into fifth and sixth components in phase with each other and in phase with said third and fourth components, means coupling said third and fourth components to the first and second antennas respectively of said vertically spaced pair, means coupling said fifth and sixth components to the first and second antennas respectively of said horizontally spaced pair, said two pairs of antennas being arranged to transmit the signal in a concentrated beam and to receive energy reflected from an object within said beam, said second network being further adapted to resolve the signal received by said first antenna of said vertical pair into seventh and eighth components respectively and to resolve said signal from said second antenna of said vertical pair into ninth and tenth components respectively, said seventh and ninth components being in phase opposition and said eighth and tenth components being in phase with each other, said second network providing a first output signal to said first network proportional to the vector sum of said eighth and tenth components and a second output signal proportional to the vector difference of said seventh and ninth components, said third network being further adapted to resolve the signal from said first antenna of said horizontal pair into eleventh and twelfth components respectively, and to resolve the signal received by the second antenna of said horizontal pair into thirteenth and fourteenth components respectively, said eleventh and thirteenth components being in phase opposition, said twelfth and said fourteenth components being in phase, said third network providing a first output signal to said first network proportional to the vector sum of said twelfth and fourteenth components and a second output signal proportional to the vector difference of said eleventh and thirteenth components respectively, said second output signals of said second and third networks respectively being indicative of the position of the source of received energy with respect to said antennas.

7. A directive radio system as in claim 6 wherein said first, second and third networks are electrically and mechanically passive.

8. A directive radio system as in claim 6 wherein said first network produces a first output signal in response to said first output signals from said second and third networks respectively, said system further comprising a local oscillator, a first mixer responsive to said second output of said second network and a signal from said local oscillator for producing a first intermediate frequency signal, a second mixer responsive to said second output of said third network and a signal from said local oscillator for producing a second intermediate frequency signal, a third mixer responsive to said first output signal of said first network and a signal from said local oscillator for producing a third intermediate frequency signal, a fourth mixer responsive to said first and third intermediate frequency signals, and a fifth mixer responsive to said second and third intermediate frequency signals, the output signals of said fourth and fifth signals being indicative of the position of the source of receiver signals with respect to said antennas.

9. A directive radio receiving system comprising, first, second, third and fourth antennas arranged at the corners of a rectangle, said antennas being further arranged for simultaneously receiving individual portions of the radiation from a particular source thereof, first means for resolving the signal received by said first antenna into first and second components each spaced in phase with respect to said last-mentioned received signal and for resolving the signal received by said second antenna into third and fourth components, said third component being in phase with said first component and said fourth component being in phase opposition to said second component, said first means being further adapted to provide a first output signal proportional to the vector sum of said first and third components and a second output proportional to the vector difference of said second and fourth components, second means for resolving the signal received by said third antenna into fifth and sixth components each spaced in phase with respect to said last-mentioned received signal and for resolving the signal from said fourth antenna into seventh and eighth components, said fifth and seventh components being in phase and said sixth and eighth components being in phase opposition, said second means being further adapted to provide a first output signal proportional to the vector sum of said fifth and seventh signals and to provide a second output signal proportional to the vector difference of said sixth and eighth components, third means for resolving said first output signal of said first means into ninth and tenth components each spaced in phase with respect to said first output signal of said first means and for resolving said first output signal of said second means into eleventh and twelfth components said eleventh component being in phase with said ninth component and said twelfth component being in phase opposition to said tenth component, said third means further providing a first output signal proportional to the vector sum of said ninth and eleventh components and a second output signal proportional to the vector difference of said tenth and twelfth components, and fourth means for resolving said second output of said first means into thirteenth and fourteenth components each spaced in phase with respect to said second output signal of said first means and for resolving said second output signal of said second means into fifteenth and sixteenth components, said fifteenth component being in phase with said thirteenth component and said sixteenth component being in phase opposition to said fourteenth component, said fourth

means being further adapted to provide a first output signal proportional to the vector sum of said thirteenth and fifteenth components, said first output of said fourth means and said second output of said third means being indicative of the angular position of said source with respect to said antennas.

10. A directive radio receiving system comprising first, second, third and fourth antennas arranged at successive corners of a rectangle, said antennas being further arranged for simultaneously receiving individual portions of the radiation from a particular source thereof, resolving means coupled to said antennas for resolving the signals from each of said antennas into first components each in phase with a reference phase position and second components each in phase quadrature with said reference phase, said resolving means being further adapted to provide a first output signal proportional to the vector sum of said first components, a second output signal proportional to the vector sum of the vector difference of said second components of the signal from said first and second antennas respectively and the vector difference of said second components of the signal from said fourth and third antennas respectively, and a third output signal proportional to the vector difference of the vector sum of said second components of the signals from said first and second antennas respectively and the vector sum of said second components of said signals from said third and fourth antennas respectively.

11. A directive radio receiving system as in claim 10, said system further comprising first, second and third mixer circuits, means coupling said first, second and third output signals to said first, second and third mixers respectively, a local oscillator, means coupling said local oscillator to said first, second and third mixers whereby said first mixer produces a first intermediate frequency signal, said second mixer produces a second intermediate frequency signal and said third mixer produces a third intermediate frequency signal, a fourth and a fifth mixer, means coupling said first and second intermediate frequency signals to said fourth mixer and means coupling said first and said third intermediate frequency signals to said fifth mixer, said fourth and fifth mixers producing first and second error signals respectively, said error signals being indicative of the angular position of said source with respect to said antennas.

12. A directive radio receiving system as in claim 10 wherein said resolving means comprises a mechanically and electrically passive network.

13. A directive radio receiving system as in claim 10, said system further comprising a transmitter, means coupling said transmitter to said resolving means, said resolving means being further adapted to couple the energy from said transmitter to said four antennas equally and in phase.

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