TWO-FEED "X" BAND ANTENNA

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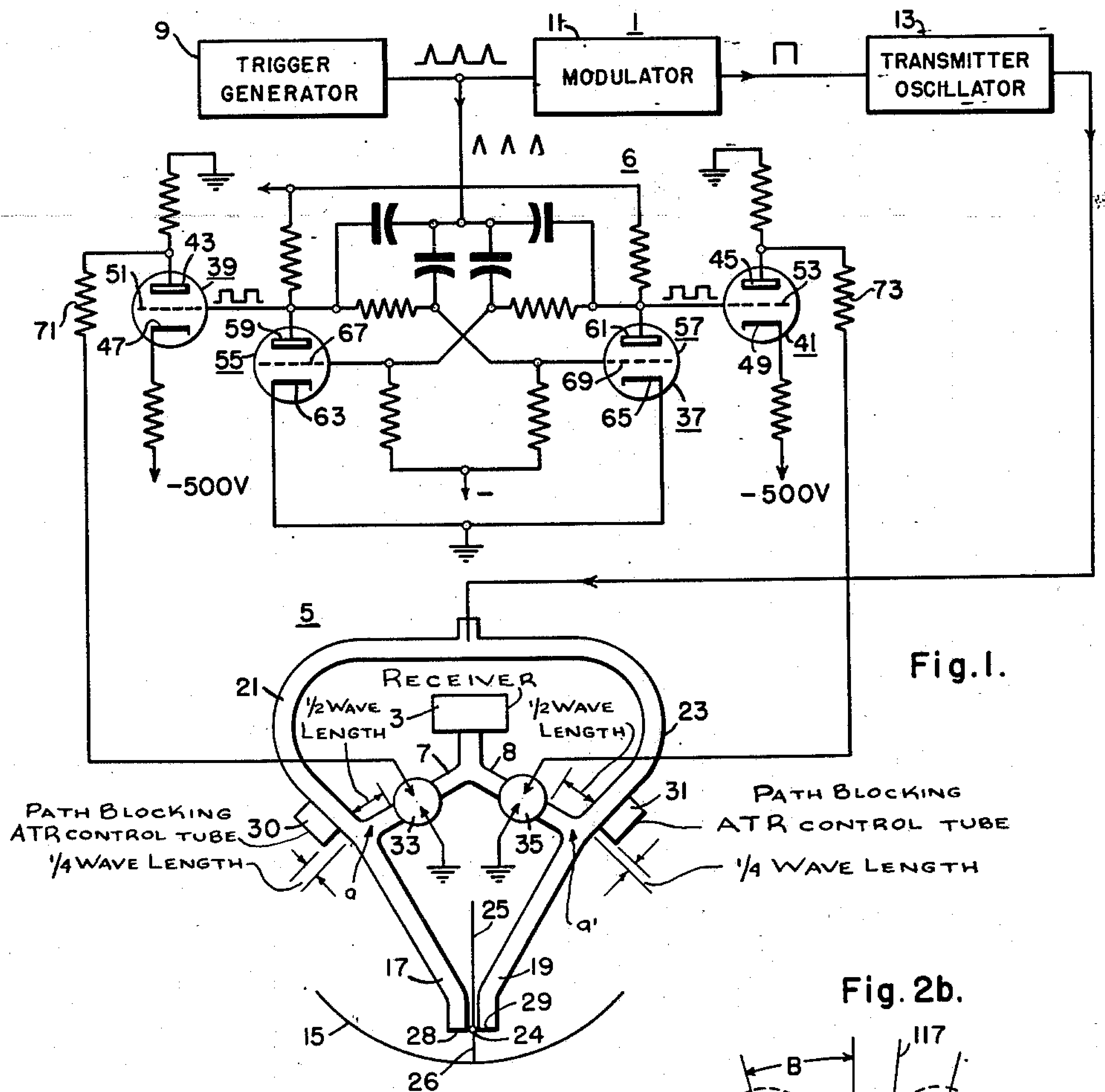


Fig. 1.

Fig. 2b.

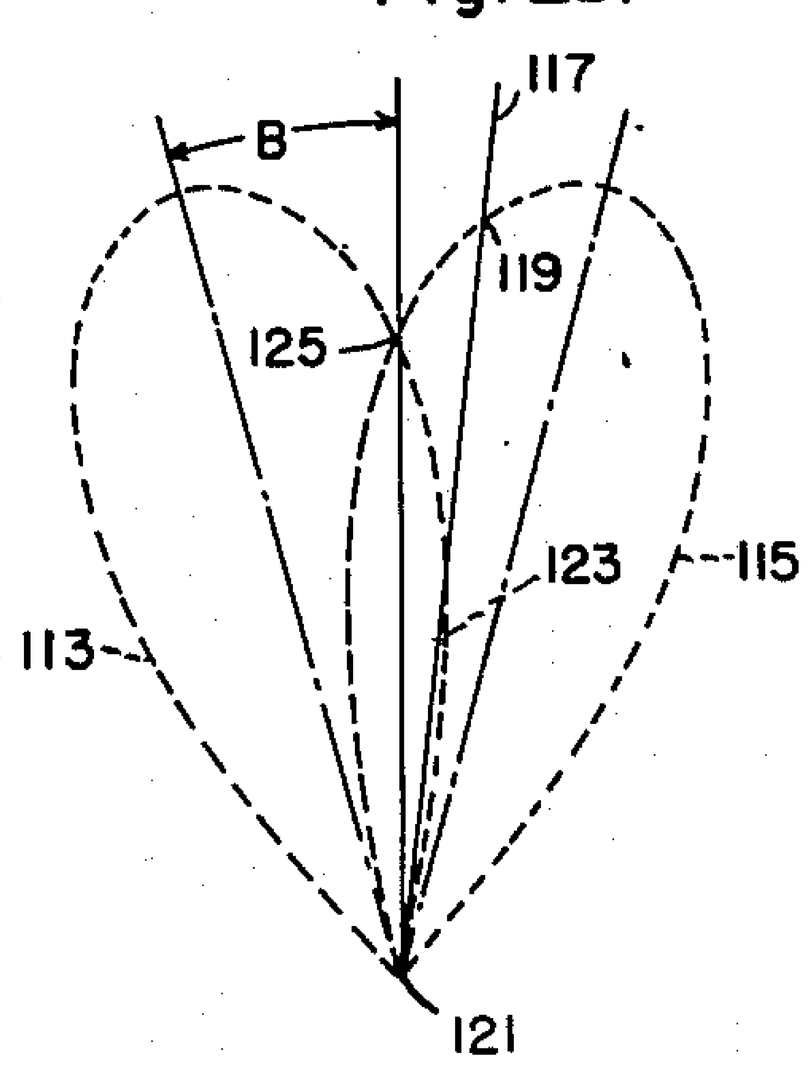
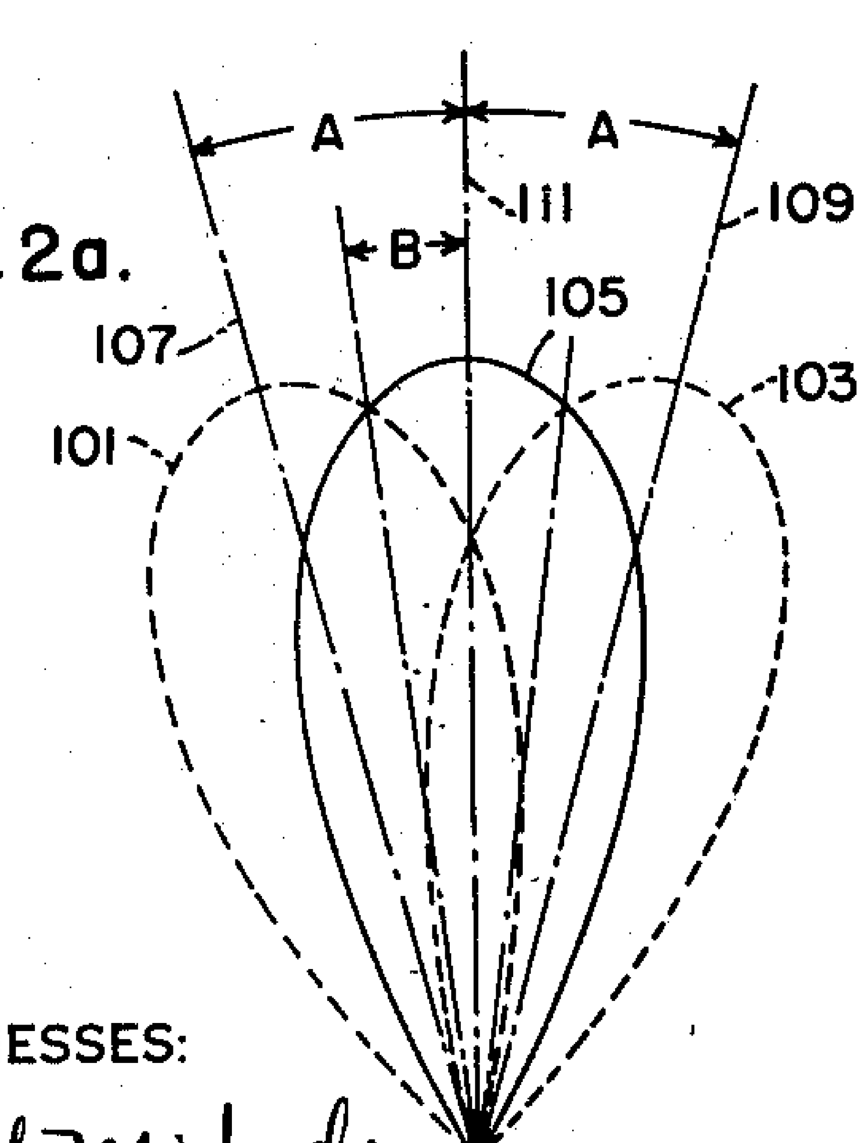


Fig. 2a.



WITNESSES:
Edward Michaels
Wm. C. Groome

INVENTORS
William S. Parnell &
John W. Taylor, Jr.
BY
Hymen Diamond
ATTORNEY

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TWO-FEED "X" BAND ANTENNA

William S. Parnell and John W. Taylor, Jr., Baltimore, Md., assignors, by mesne assignments, to the United States of America as represented by the Secretary of the Navy

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4 Claims. (Cl. 250—13)

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Our invention relates to systems for the detection of distant objects and, more particularly, to such systems for determining the direction and distance of objects. It concerns itself with systems in which the antenna lobes are switched periodically and direction is determined by comparing signals received on the two lobe positions. Apparatus in accordance with our invention is designed primarily for use in guided missiles. Lobe switching apparatus for detecting distant objects constructed in accordance with the prior art is typified by Beck Patent 2,409,183. In such apparatus, wave guides are used as the antenna elements and a single reflector is used for both guides, transmission occurs out of one wave guide at a time. The transmit antenna patterns are identical to the receive antenna patterns, except for the effect of the lobe switching mechanism between the time the pulse is transmitted and the time it is received. This mechanism of the prior art alternately tunes and detunes the wave guides. In accordance with the teaching of the prior art, it is mechanically controlled and the switching rate is low. Since the signal reflected from targets, ships, and planes in particular, fluctuates as much as 30 db, the more rapidly the signals from left and right beams can be compared, the less chance the returning signal has to vary. Further, when the transmit and receive patterns are identical and in each of the lobe positions are coincident, the pattern which results from plotting the products of the vectors of one pattern by the vectors of the other, which we shall define as the directional sensitivity pattern, will have a beam separation for the two lobe positions, that is an angular separation of the peaks of the patterns, equal to that of the transmit and receive patterns. This beam separation of the directional sensitivity patterns is larger than desired because of the geometrical limitations of the feed structure. We have found that this condition causes excessive loss of effective power when on-target; that is, when the received energies on each of the lobes are equal. Such loss is a decided disadvantage in a guided missile.

Prior art apparatus for detecting objects of another type is exemplified in the Hoffman Patent 2,424,984. In Hoffman's apparatus, the antennas are of the dipole type. Transmission occurs from both antenna elements simultaneously and then reception alternately at one or the other antenna elements. The lobe switching is effected electronically. The direction of the receive patterns depend on the difference in electrical lengths of the transmission paths to the two antenna elements and, therefore, varies as the transmitter frequency drifts. Because of this variation, the angle between the lobes and, therefore, the accuracy of the lobe switching mechanism is critically dependent on frequency.

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In guided missile work, it is necessary that the auto pilots or servo systems which control the flight of the missile receive stable error information, that is, stable information as to deviation from the target. As the servo sees it, fluctuations in strength of returning signals by reason of the physical characteristics of the target are the same as fluctuations in antenna angle. The servo, therefore, responds similarly to signals of both types and the flight is unstable. It is desirable, therefore, to make as rapid as possible comparisons between the energies received over the two receive patterns or lobes.

It is accordingly an object of our invention to provide a radar system which shall have the compactness, the accuracy and the freedom from frequency sensitivity indispensable to guided missile use.

An ancillary object of our invention is to provide a lobe switching system independent of frequency, in which the switching between lobes shall be effected electronically.

Another ancillary object of our invention is to provide a lobe switching system of the small dimensions indispensable to guided missiles, which shall have a high degree of directional sensitivity and at the same time shall transmit a maximum of energy in the on-target direction

A further ancillary object of our invention is to provide a lobe switching system suitable for operation at high frequencies which shall include lobes.

A still further object of our invention is to provide a radar impulse system of the lobe switched type which shall be suitable for operation at high frequencies, shall have a high directional sensitivity and shall be capable of transmitting a maximum of energy in the on-target direction.

In accordance with our invention, we provide an antenna lobe switching system having electronic switching between lobes in which the lengths of the transmission paths to the antenna elements are not critical. Control means is also provided for transmitting simultaneously out of both antenna elements and then receiving energy on only the left antenna element, transmitting again out of both antenna elements and this time receiving energy only on the right antenna element. This control means may be of any general type but in accordance with the specific aspects of our invention include a multivibrator of the Eccles-Jordan scale of two type and discharge devices responsive to the plate outputs of the multivibrator and located in or alongside the transmission paths from the transmitter and receiver means.

In the specific practice of our invention, the transmission paths to the antenna elements and the antenna elements themselves are wave guides. When using these wave guides, the effective operation of the equipment is not affected by changes in frequency during operation.

The novel features that we consider characteristic of our invention are set forth with particularity in the appended claims. The invention itself, however both as to its organization and its method of operation, together with additional objects and advantages thereof, will be understood from the following description of specific embodiments thereof when read in connection with the accompanying drawing, in which:

Figure 1 is a schematic diagram of apparatus and circuits of an embodiment of our invention;

Figure 2*a* is a diagram showing the transmit and receive lobe patterns of the apparatus shown in Fig. 1; and

Figure 2*b* is a diagram showing the directional sensitivity patterns resulting from the transmit and receive patterns shown in Fig. 2*a*.

Referring to Figure 1, the drawing of the apparatus comprises four main parts. The first two main parts are the transmitter means 1 and the receiver means 3. The third main part is an antenna structure 5 to which energy is conveyed from the transmitter means. This antenna structure 5 likewise receives the reflected energy and control means 6 are provided for blocking transmission of received energy through only one of the transmission paths 7 and 8 to the receiver means 3 after the transmission of impulse energy, blocking the transmission of received energy to the other transmission path 7 or 8 to the receiver means 3 after the next impulse is transmitted, thus alternately blocking the transmission paths 7 and 8. This control means 6 also blocks transmission of energy to the receiver means 3 during the instants of transmission of impulse energy from the transmitter means 1. The control means 6 for accomplishing this constitutes the fourth main part.

The transmitter means 1 consists of a trigger generator 9, a modulator 11 and a transmitter oscillator 13, which in the preferred practice of our invention may be a magnetron. This transmitter means 1 may be of any standard type known in the art. The receiver means 3 is likewise of standard type.

The third main part, the antenna structure 5, comprises a reflector 15, antenna elements 17 and 19, and transmission paths 7, 8, 21 and 23, leading to the antenna elements 17 and 19. The reflector 15 in the specific embodiment of our invention is a parabolic reflector. This parabolic reflector 15 has a focal point 24, an axis 25, and a vertex 26. Each of the antenna elements 17 and 19 comprise a wave guide having apertures 28 and 29, respectively, facing the reflector 15. Two transmission paths 21 and 23 connect the transmitter means 1 to the antenna elements 17 and 19. Two transmission paths 7 and 8 also connect the receiver means 3 to the antenna elements 17 and 19. In the specific embodiment of our invention, these four transmission paths 7, 8, 21 and 23 are wave guides. The transmission paths 21 and 23 have means for blocking return

to the transmitter of energy transmitted through them. In the specific embodiment of our invention, this means for blocking the return of energy through the two transmission paths 21 and 23 to the transmitter means 1 from the antenna elements 17 and 19 are ATR (anti transmisser-receiver) tubes 30 and 31, one in each path. When these ATR tubes 30 and 31 are nonconductive they constitute an open circuit in the transmission paths 21 and 23 blocking flow of energy along the transmission path. When the transmitter means 1 is triggered these tubes 30 and 31 break down for the period of the high energy transmitted pulse so as to permit energy to flow to the antenna elements 17 and 19 from the transmitter means 1. Discharge devices 33 and 35 which form a part of control means 6 are provided for blocking the transmission of transmitted and received energy through the transmission paths 6 and 7 under the proper circumstances. In the specific embodiment of our invention, these devices are TR (transmitter-receiver) tubes 23 and 35. When either of these tubes 33 or 35 breaks down, it short circuits its corresponding path preventing flow of energy through it to the receiver means 3.

The ATR tubes 30 and 31 are located a distance of ¼ wave length along the wave guide away from the junction points a and a^1 of the guides 7 and 17 and 8 and 19, respectively. The TR tubes 33 and 35 are located a distance of ½ wave length along the wave guide away from the junction points a and a^1. When these tubes 30, 31, 33 and 35 are so located substantially no R. F. energy is reflected within the wave guides 7, 8, 21 and 23, either on transmission or reception. The ATR tubes 30 and 31 are located on the sides of the transmission paths or wave guides 21 and 23 and when energy from the transmitter means 1 is transmitted through the wave guides 21 and 23, the ATR tubes 30 and 31 fire and allow the passage of the energy to the antenna elements 17 and 19. The TR tubes 33 and 35 are located within the wave guides 7 and 8 which connect the receiver means 3 to the antenna elements 17 and 19. These TR tubes 33 and 35 on being fired prevent the transmission of energy through the wave guides 7 and 8. Therefore, when energy is transmitted from the transmitter means 1, these TR tubes 33 and 35 fire and none of this transmitted energy can get to the receiver means 3.

The received energy, that is, the energy that is returned after having been reflected off an object, is not sufficient to fire either the TR or ATR tubes 30, 31, 33 or 35. Thus provision has to be made for allowing the received energy to be picked up or received by the receiver means 3. This is taken care of by control means 6 which alternately fires the two TR tubes 33 and 35.

The control means 6 or the fourth main part comprises a multivibrator 37, two control discharge devices 39 and 41 having anodes 43 and 45, cathodes 47 and 49, and control electrodes 51 and 53, respectively, and the two TR tubes 33 and 35 hereinbefore mentioned. The multivibrator 37 is responsive to the transmitter means 1 and more particularly to the output of the trigger generator 9. The multivibrator 37 shown is an Eccles-Jordan scale of two multivibrators; however, any suitable multivibrator may be used. The multivibrator 3, comprises two discharge devices 55 and 57, each discharge device 55 and 57 having anodes 59 and 61, cathodes 63 and 65, and control electrodes 67 and 69. The control discharge devices 55 and 57 are responsive to the plate outputs of the multivibrator 37, there being a connection from the anode 59 of the first multivibrator discharge device 55 to the control electrode 51 of the control discharge device 39 and a connection from the anode 61 of the second multivibrator discharge device 57 to the control electrode 53 of the other control discharge device 41. The anodes 43 and 45 of the two control discharge devices 39 and 41 are connected to the two TR tubes 33 and 35 through current limiting resistors 71 and 73 as shown.

Referring to Figures 2*a* and *b* of the drawing, the patterns 101 and 103 represent the reception lobes and pattern 105 represents the radiation pattern for transmission. This configuration represents simultaneous transmission out of both of the antenna elements (one lobe 105) and then alternate reception of reflected energy by first one antenna element 17 or 19 and then the other (lobes 101 and 103).

The angle A which the axes 107 and 109 of these directional reception patterns 101 and 103 each make with the axis 111 of transmitted energy may be approximately determined from the physical disposition of the antenna elements 17 and 19 with respect to the vertex 26 of the parabolic reflector 15. To achieve maximum range, or radar sensitivity, it is desirable that angle A be as small as practicable still maintaining lobe separation.

Angle A can be varied by changing the physical disposition of the antenna elements 17 and 19 with respect to the vertex 26 of the parabolic reflector 15 (as was explained in the preceding paragraph), that is, by utilizing a reflector having a larger or smaller focal distance. The angle A would become smaller if the antenna elements 17 and 19, which are located at the focal point, were mounted farther from the parabolic reflector 15—in other words, if a reflector were used having a larger focal length. However, by mounting the antenna elements 17 and 19 further away from the parabolic reflector 15, either a larger diameter parabolic reflector or more directive feeds have to be used so as to prevent loss of energy over the edge of the dish. Moreover, even if space requirements would permit a larger parabolic reflector, this would make the receive and directional sensitivity patterns 101, 103, 113 and 115 more directive (have a smaller beam width), and the cross-over level of the receive and directional sensitivity patterns 101, 103, 113 and 115, which determine radar sensitivity, would remain essentially constant. The other alternative, more directive feeds, requires larger feed apertures and, hence, wider feed spacing. And when the feed spacing is increased, the beam separation of the receive and directional sensitivity patterns 101, 103, 113, and 115 is increased to the same value with which we began. To summarize, the parabola size, the focal length, and the feed separation all have an effect on the cross-over level of the patterns. However, the interrelations between these variables is such that the maximum cross-over level using two feeds is independent of them. After a maximum has been attained, changing one of the variables necessitates a change in one of the others which counteracts the effect on the cross-over level. In the specific embodiment of our invention, a primary consideration is making the feed apertures 28 and 29 as small as possible so that the effect on the aperture of the reflector 15 will be negligible. The choice of plain wave-guide feeds to attain this and the limitation of parabola diameter completely specify all other dimensions. Therefore, the antenna elements 17 and 19 have their apertures 28 and 29 respectively located at the focal point 24 of the parabolic reflector 15 and both antenna elements 17 and 19 have their sides close to the axis 25 of the reflector 15.

The transmit pattern 105 represents the variation in amount of energy impinging on a target as a function of its bearing. The receiver patterns 101 and 103 in turn represent the amount of energy which will be picked up as a function of the direction from which energy comes. Therefore, the patterns of directional sensitivity 113 and 115, the energy picked up from a target as a function of its bearing, is determined by the product of the transmit energy in any direction by the receive energy in that direction—that is, graphically the product of the patterns.

The directional sensitivity is graphically the product of the patterns. In other words if the received intensity is $R\angle\theta$ and the transmit, $T\angle\theta$, the directional signal $RT\angle\theta$. The vector product would give $RT\angle 2\theta$.

It should be noted that if the receive patterns 101 and 103 are separated by the angle 2A, the directional sensitivity lobes 113 and 115 are separated by only half this angle, assuming that both transmit and receive patterns 105, 101 and 103 are identical in shape. This can be easily seen by considering the point of intersection of one receive pattern with the transmit pattern. For angles greater or less than that corresponding to this point, the vector determined by one pattern decreases faster than the vector determined by the other increases, so the maximum product of directional sensitivity occurs at this angle A/2 or B.

Assume a target 117 is located in the direction shown. A signal whose intensity is indicated by the radius vector to the point 119 from point 121 in the direction 117 is received by the antenna when operating in accordance with the right lobe. A signal whose intensity is indicated by the radius vector to the point 123 is received by the antenna when operating according to left lobe. The difference between these two vectors determines the error signal, the indication of how far the antenna structure 5 is pointing away from the target 117. The intersection point 125 of the two directional sensitivity patterns 113 and 115 determines both (A) the intensity of the signal returned when the antenna structure 5 is on-target and (B) the rate of change of error signal as a function of target bearing. We define (A) as the radar sensitivity, the ability of the radar equipment to pick up weak signals. We define (B) as the error sensitivity, the accuracy to which the antenna structure 5 may be pointed at the target. Changing the cross-over lever 125 will increase one sensitivity at the expense of the other. It is generally considered that the best compromise between radar sensitivity and error sensitivity is accomplished by having the cross-over level at half power or 3 db down from the peak.

We have found that in a system according to our invention in which the transmit lobe is maintained fixed and the receive lobe is switched, the maximum radar sensitivity is attainable while maintaining effective directional sensitivity. The improvement in sensitivity over prior art systems may result in an increase in range as high as 20%.

The operation of the apparatus shown in Figure 1 is as follows:

Energy is transmitted out of both antenna elements 17 and 19. Then reflected or received energy is received on the left feed or antenna element 17 with the right antenna element 19 blocked by means of a TR tube 35 in conjunction with the remainder of control means 6. Energy is then again transmitted out of both antenna elements 17 and 19. This time the left antenna element 17 is blocked by means of the TR tube 33 in conjunction with the rest of control means 6 and the energy is received on the right antenna element 19. This operation is continually repeated receiving energy alternately on the left and the right antenna elements 17 and 19 respectively.

Pulses from the magnetron 13 split at the wave guide junction of transmission paths 21 and 23 fire all the ATR and TR tubes 30, 31, 33 and 35 respectively, and then proceed out both feeds or antenna elements 17 and 19 in phase to the parabolic reflector 15. The energy is reflected off the parabolic reflector 15 and forms the radiation pattern 105 shown in Figure 2. Received signals returning through these antenna elements 17 and 19 are blocked from each other and from the transmitter means 1 by the ATR tubes 30 and 31 and then proceed through the unfired TR tube 33 or 35 to the receiver means 3. The two TR tubes 33 and 35 are alternately fired by means of the multivibrator 37 and the two control discharge devices 39 and 41 so that after the transmission of a pulse, received energy can reach the receiver means 3 through only one of the transmission paths 7 or 8, the other path being blocked by the TR tube 33 or 35. When the next pulse is transmitted the multivibrator 37 trips and the control discharge device 39 or 41 which is made conductive by the multivibrator 37 blocks the transmission path 7 or 8 that had previously allowed the transmission of received energy through it and unblocks the other transmission path 7 or 8 to the receiver means 3. Thus the reception will be as shown by the two lobes 101 and 103 in Figure 2.

The multivibrator is such that the outputs taken off of the anodes 59 and 61 of the two discharge devices 55 and 57, forming a part of the multivibrator 37 are 180 degrees out of phase. The multivibrator 37 is responsive to the output of the trigger generator 9 and the control discharge devices 39 and 41 are responsive to the outputs of the multivibrator 37. As a pulse is sent out from the trigger generator 9 to operate the modulator 11 and magnetron 13 for transmission purposes, a like pulse in phase with the pulse to the modulator 11 and magnetron 13 causes the multivibrator 37 to trip in one direction or the other. Since the outputs of the multivibrator 37 are 180 degrees out of phase, only one of the control discharge devices 39 or 41 will conduct at any one time. When the multivibrator 37 receives another pulse from the trigger generator 9 the opposite discharge device 39 or 41 conducts. The discharge devices 39 and 41 fire alternately, one being in the fired condition all the time. Each of the TR tubes 33 and 35 are responsive to the output of one of the control discharge devices 39 or 41. Thus when one of the control discharge devices 39 or 41 is conducting the TR tube 33 or 35 that is responsive to its output will have been fired serving to block the transmission of energy in that transmission path 7 or 8. When the other control discharge 39 or 41 is conducting, the other TR tube 33 or 35 will be fired thus blocking the transmission of energy in its transmission path 7 or 8.

It is to be understood by those skilled in the art that any suitable transmitter or receiver means 1 or 3 can be used with the apparatus shown.

It is to be further understood by those skilled in the art that any suitable multivibrator could be used in the place of the one 37 shown. Variations in multivibrators might include switching at some other time than at transmission, operation of discharge devices 39 and 41 for short periods of time to cover targets within a limited variation of range, etc.

It is to be further understood by those skilled in the art that any suitable control means could be substituted for the control discharge devices 39 and 41 shown.

It is to be further understood by those skilled in the art that any suitable blocking means could be used in place of the ATR and TR tubes 30, 31, 33 and 35 respectively shown.

It is to be still further understood by those skilled in the art that any suitable reflector can be used in the place of the parabolic reflector 15 shown. The antenna elements 17 and 19 can also, if desired, be located further apart, that is a certain distance away from the focal line 25 of the reflector 15.

It is to be still further understood by those skilled in the art that any other suitable type of feed structure such as polyrods, slot antenna, etc., may be used in the place of the plain wave guides.

Although we have shown and described certain specific embodiments of our invention, we are fully aware that many modifications thereof are possible. Our invention, therefore is not to be restricted except insofar as is necessitated by the prior art and by the spirit of the appended claims.

We claim as our invention:

1. A radio impulse system, comprising a transmitter, a receiver, a concave reflector having a focal point, a pair of antenna elements substantially equally spaced from said focal point, each of said antenna elements comprising a wave guide having an aperture facing said reflector, a first wave guide section connecting said transmitter to one of said antenna elements, a second wave guide section connecting said transmitter to the other of said antenna elements, a third wave guide section connecting said receiver to said first wave guide section, and a fourth wave guide section connecting said receiver to said second wave guide section.

2. A radio impulse system, comprising a transmitter, a receiver, a concave reflector having a focal point, a pair of antenna elements substantially equally spaced from said focal point, each of said antenna elements comprising a wave guide having an aperture facing said reflector, a first wave guide section connecting said transmitter to one of said antenna elements, a second wave guide section connecting said transmitter to the other of said antenna elements, a third wave guide section connecting said receiver to said first wave guide section, a fourth wave guide section connecting said receiver to said second wave guide section, and control means synchronized with said transmitter for alternately blocking said third and fourth wave guide sections.

3. A radio impulse system, comprising a trans-

mitter, a receiver, a concave reflector having a focal point, a pair of antenna elements substantially equally spaced from said focal point, each of said antenna elements comprising a wave guide having an aperture facing said reflector, a first wave guide section connecting said transmitter to one of said antenna elements, a second wave guide section connecting said transmitter to the other of said antenna elements, a third wave guide section connecting said receiver to said first wave guide section, a fourth wave guide section connecting said receiver to said second wave guide section, control means synchronized with said transmitter for alternately blocking said third and fourth wave guide sections, and means responsive to transmission of energy from said transmitter for blocking said third and fourth wave guide sections while unblocking said first and second wave guide sections.

4. The invention in accordance with claim 3 characterized by the part of said means responsive to the transmission of energy from said transmitter for blocking said third and fourth wave guide sections being located one-half wave length from the junctions of said first and third, and second and fourth wave guide sections, respectively, and by the part of said means responsive to transmission of energy from said transmitter for unblocking said first and second wave guide sections being located one-quarter wave length from said junctions, respectively.

WILLIAM S. PARNELL.
JOHN W. TAYLOR, JR.

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