

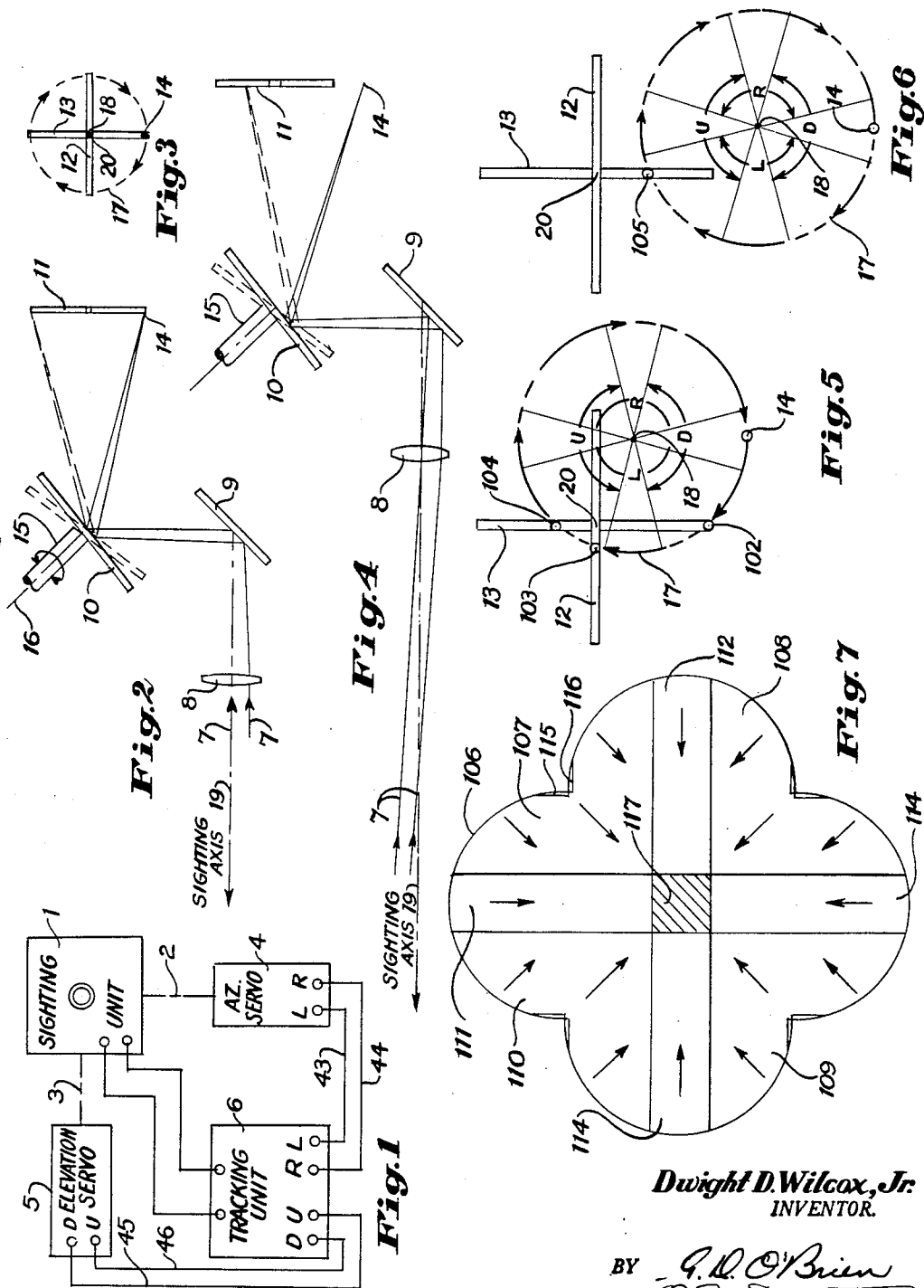
Aug. 22, 1961

D. D. WILCOX, JR
TARGET TRACKING SYSTEM

2,997,588

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2 Sheets-Sheet 1



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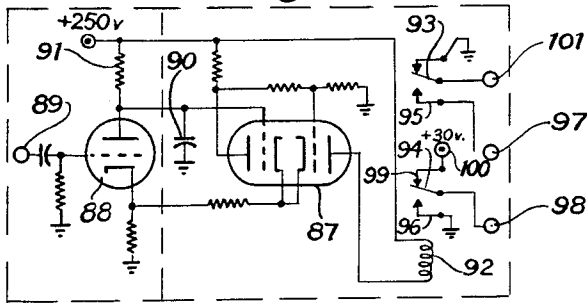
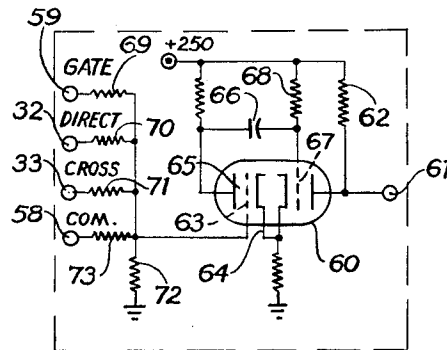
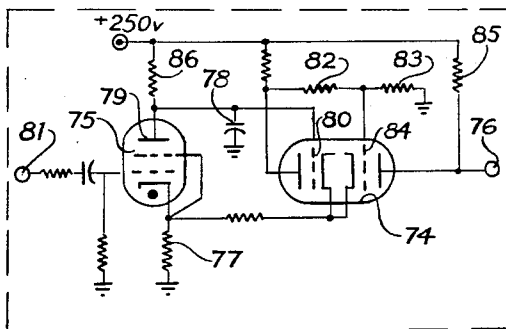
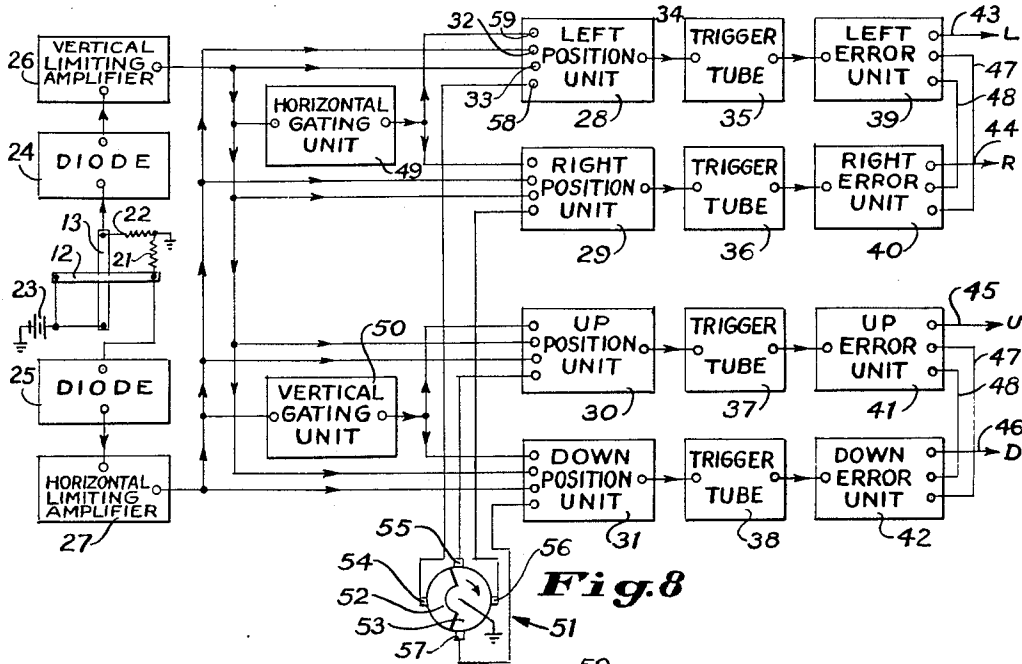
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D. D. WILCOX, JR
TARGET TRACKING SYSTEM

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2 Sheets-Sheet 2



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2,997,588

TARGET TRACKING SYSTEM

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mesne assignments, to the United States of America as
represented by the Secretary of the Navy
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This invention relates to an improved target tracking system by means of which a sighting device may be kept trained upon a desired target. It is particularly intended for use in a system employing the infrared radiations from a target.

Many arrangements have been proposed having the general purpose of providing a device for continuously tracking a target by means of a suitable sighting apparatus wherein any deviation of the sighting axis from the target will produce corrective signals which may be utilized either indirectly, through the agency of an operator, or directly, by means of suitable servo-mechanisms, to shift the sighting axis until it is again coincident with the line of sight to the target. However, most of these known arrangements utilize either radio or light waves reflected from the target and are open to certain objections. For example, the type employing radio waves, such as is exemplified by radar apparatus is readily susceptible to jamming by suitable electronic equipment operated by the enemy. Similarly, optical sighting devices are limited in their usefulness to conditions where moderately clear visibility is maintained at all times. There is clearly a need therefore for a tracking arrangement which is effective regardless of visibility conditions and is substantially immune from enemy jamming action.

It is an object of this invention to provide such a tracking system which is responsive to infrared rays emanating from the target.

It is a further object to provide such a tracking system which is capable of providing a correction signal which may be utilized, without ambiguity, to correct any appreciable deviation between the sighting axis and the actual line of sight to the target.

Another object is to provide a tracking system which is relatively simple and inexpensive and which will respond readily to deviations of any real importance between the sighting axis and the actual line of sight to the target, but which will be insensitive to minor deviations and thereby avoid unnecessary control corrections.

A still further object is to provide such a tracking apparatus having a relatively wide field of coverage; that is, a system which will, when once aimed in the direction of a selected target, tend to follow the target regardless of fairly substantial alignment errors which may arise from time to time therebetween.

Further objects will become apparent from the following specification, especially when considered in the light of the accompanying drawing.

In the drawing:

FIG. 1 is a block diagram of a complete automatic tracking system embodying the present invention;

FIG. 2 is a diagrammatic view of the infrared scanning system employed therein;

FIG. 3 is a diagrammatic view illustrating the manner in which the scanning spot produced by the sighting unit is related to the sensing element thereof when the sighting axis is "on-target";

FIG. 4 is a diagrammatic view similar to FIG. 2 and showing the relationships involved when the sighting axis is not aimed directly at the target;

FIGS. 5 and 6 are diagrammatic views to illustrate the operation of the device;

FIG. 7 is a diagram of the effective field of coverage of the tracking system;

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FIG. 8 is a block diagram of the tracking unit shown in FIG. 1;

FIG. 9 is a schematic diagram of one of the target position signal generating units shown in FIG. 8;

FIG. 10 is a schematic diagram of one of the gating units shown in FIG. 8; and

FIG. 11 is a schematic diagram showing one of the trigger tubes and error signal generating units shown in FIG. 8.

A block diagram of a typical automatic tracking system to which this invention may be applied is shown in FIG. 1. A suitable sighting unit 1 is adapted to be shifted about a pair of rectangularly related axes (shown as azimuth and elevation axes 2 and 3) by the azimuth and elevation servo-mechanisms 4 and 5 respectively. These servos are in turn controlled by the output of a tracking unit 6 which is responsive to the output from the sighting unit to generate output signals in event of any appreciable misalignment between the sighting axis and the actual line-of-sight to a given target, the output signals being of such character as to cause the operation of one or both of the servo-mechanisms in the proper direction to reduce the misalignment toward zero.

The sighting unit 1 may incorporate an infrared scanning system such as is shown in FIG. 2. In this figure the rays of infrared energy 7, radiating from a target (not shown) are directed by means of a suitable optical system, diagrammatically indicated as a lens 8, and a pair of mirrors 9 and 10 onto an infrared-sensitive sensing unit 11. Sensing unit 11 comprises a pair of rectangularly related elongated sensing elements 12 and 13 arranged in the form of a symmetrical cross, the arms of which define a pair of rectangularly related coordinate axes corresponding to the axes 2 and 3. For ease of description, element 12 will hereafter be referred to as the horizontal sensing element and element 13 as the vertical sensing element, since these coordinate axes are assumed to be defined thereby, although it is to be clearly understood that any appropriate pair of coordinate axes may be utilized. As indicated in FIGS. 2, 3, and 4, the rays of infrared energy from the target are focused by the lens 8 into an infrared image of the target in the plane of the sensing unit 11, the image constituting a scanning spot, designated as 14 in these figures. Mirror 10 is carried on a rotating shaft 15, the axis 16 of which is slightly offset from the perpendicular to the plane of the mirror 10. As a result, upon rotation of the shaft, the image or scanning spot 14 will be caused to continuously traverse a substantially circular scanning path 17 in the plane of the sensing unit 11 as shown in FIG. 3. The center 18 of this scanning path represents the actual line of sight to the target and the arrangement is such that, when the sighting axis, indicated at 19 in FIGS. 2 and 4, is exactly in alignment with the line of sight to the target, the scanning path will intersect each of the four arms of the cross closely adjacent the tips thereof as shown in FIGS. 2 and 3, and the center 18 will coincide with the point of intersection 20 of the elements 12 and 13.

When the sighting axis is not aimed directly at the target, the scanning path representing the target will be displaced in a corresponding direction, and to a corresponding extent, from the intersection 20 of the elements 12 and 13. FIGS. 4 and 5 represent one such situation, it being assumed that the sighting axis 19 is aimed somewhat below and to the right of the target. It will be noted that under these conditions the center 18 of the scanning circle 17 is displaced below and to the right of the intersection 20 of the arms 12 and 13 and that the scanning spot 14 will only traverse three of the four arms of the cross.

The exact nature of the sensing elements forms no part

of this invention. Suffice it to point out that each of the elements 12 and 13 is formed of one of the well known infrared-sensitive materials, of the type wherein the resistance will decrease when it is subjected to infrared energy. Thus, when elements 12 and 13 are connected in series with resistors 21 and 22 across a voltage source 23 as shown in FIG. 8, a positive-going output pulse will be produced each time the scanning spot traverses an element and will constitute an output signal from that particular element.

From the above it can be seen that the number and relative timing of the output pulses will depend upon the relative position of the sighting axis with respect to the true line of sight to the target, as represented by the position of the center 18 of the scanning circle relative to the intersection 20 of the elements 12 and 13. The apparatus, constituting the tracking unit 6 of FIG. 1, for determining the relative displacement of the sighting axis from the target from the number and relative timing of the output signals from the horizontal and vertical sensing elements, and for producing correction signals which may be applied to the servo units 4 and 5 to restore the desired coincidence, is shown in block diagram form in FIG. 8.

As shown in FIG. 8, an output signal from either of the sensing elements 12 or 13 is first applied to the corresponding one of a pair of diodes 24, 25, each of which is so biased as to insure that the system will be insensitive to stray background "noise." Those pulses which are of sufficient amplitude to overcome the bias on the diodes are applied to one of a pair of associated limiting amplifiers 26, 27 which will amplify these pulses up to a uniformly high level.

Adapted to be triggered by the outputs from the vertical and horizontal limiting amplifiers are a plurality of target position signal generating units 28—31, one corresponding to each of the directions, left, right, up, and down. Each of these target positions signal generating units is provided with a direct channel input terminal 32 and a cross channel input terminal 33. As indicated in FIG. 8, the direct channel input terminals 32 for the Left and Right units are connected to the output of the horizontal limiting amplifier 27, while the cross channel input terminals 33 are connected to the output of the vertical limiting amplifier 26. Similarly, the direct channel input terminals of the Up and Down units are connected to the vertical limiting amplifier 26, while the cross channel input terminals are connected to the horizontal limiting amplifier 27. As will be later explained in more detail, each of these target position signal generating units is adapted, when in operative condition, to generate an output pulse or position signal in response to a sensing signal from either of the limiting amplifiers.

This position signal is applied in turn to the corresponding one of four trigger tubes 35—38, one associated with each of the target position signal generating units, causing the corresponding trigger tube to fire, to in turn initiate the operation of a corresponding error signal generating unit. These error signal generating units 39—42, one for each direction, are each normally adapted to generate, when rendered operative by the corresponding trigger, an output voltage or signal which is applied through the appropriate output lead 43—46 to one of the servo units shown in FIG. 1. However, each pair of error signal generating units for opposite directions are interconnected as indicated at 47 and 48 so that when the units for opposite directions are both operating at the same time, no output signal will appear at either of their output terminals.

Whether or not the target position signal generating units will be responsive to the output from one or both of the limiting amplifiers is controlled conjointly by one or the other of a pair of gating units 49 and 50 and by a commutator 51. As shown in FIG. 8, commutator 51 has substantially 155° of its peripheral surface formed of insulating material 52, the remainder 53 being grounded at

all times. This commutator is arranged to be rotated in the direction of the arrow in synchronism with the rotation of shaft 15 and therefore in timed relation to the motion of the scanning spot about its circular scanning path 17. The commutator is shown in FIG. 8 in the position that it will assume at the instant when the scanning spot 14 is at the extreme left position of its orbital path 17. Evenly spaced about the periphery of the commutator are a plurality of contact brushes 54—57, one corresponding to, and connected to the commutator terminal 58 of, each of the target position signal generating units. At the instant assumed to be illustrated in FIG. 8, the Right, Up and Down units have their commutator terminals 58 grounded, while that of the Left unit is ungrounded.

As previously set forth, the Left and Right target position signal generating units are also controlled by the horizontal gating unit 49, which is connected to the gate input terminals 59 thereof. Similarly, the Up and Down target position units 30 and 31 are controlled by the vertical gating unit 50. As indicated in FIG. 8, the vertical gating unit 50 is responsive to the output of the horizontal limiting amplifier 27, while the horizontal gating unit 49 is controlled by that from the vertical limiting amplifier 26; that is, each is controlled by "cross channel" signals. As will be set forth in greater detail hereinafter, the arrangement is such that a particular target position signal generating unit will be insensitive to outputs from either of the limiting amplifiers whenever its commutator brush is on the grounded portion 53 of the commutator 51, but when its commutator brush is on the ungrounded portion 52, the target position signal generating unit will always be responsive to input signals appearing at its cross channel input terminal 33 and also will be responsive to signals applied to its direct channel input terminal 32 in the event that no cross channel input signal has been available during the preceding signal. With this arrangement the Left and Right target position units will normally be controlled by the cross channel output from the vertical limiting amplifier 26, and only under conditions of extreme tracking errors will they be responsive to direct channel output from the horizontal limiting amplifier 27. Similarly, the Up and Down target position signal generating units 30 and 31 will normally be controlled by the horizontal limiting amplifier 27, and but rarely by the vertical limiting amplifier 26.

FIG. 9 shows one of the target position signal generating units. It is seen that this unit comprises a duo-triode tube 60 connected in a generally conventional multivibrator circuit. This tube is so connected that normally the righthand section is heavily conducting, with the result that the voltage appearing at the output terminal 61 is relatively low due to the drop through the plate resistor 62 of this righthand section. As will hereinafter appear, when the associated gating unit is inactive, a relatively high voltage is present at the gate terminal 59 and, when the commutator terminal 58 is ungrounded, the grid 63 of the lefthand section of the tube 60 will be maintained at a positive potential just sufficiently below that of the cathode 64 thereof so that the lefthand section will be cut-off. Under these circumstances, when a positive-going pulse is applied to either the direct or cross channel input terminals 32 or 33, the grid 63 will be driven sufficiently further positive to cause the lefthand section to become conducting, producing an immediate drop in the potential at its plate 65. This drop in plate potential will be applied through condenser 66 to the grid 67 of the righthand section, blocking this latter section and causing its plate voltage to rise abruptly to substantially 250 volts. This condition will be maintained until condenser 66 has had sufficient time to be charged through resistor 68 to a voltage sufficient to again unblock grid 67, at which time the righthand section will again become conductive and the lefthand section will be returned to its cut-off condition. In the instant track-

ing system one scanning cycle is assumed to take one-tenth of a second and, under these circumstances, the values of resistor 68 and condenser 66 are selected such that the higher voltage will be present at the output terminal 61 for a period of substantially 85 milliseconds.

However, when the voltage applied to the gate input terminal 59 is at a lower value, such as will obtain when the corresponding gating unit has been triggered, only those input pulses applied to the cross channel input terminal 33 will be effective to trigger the multivibrator 60. This result is obtained by proper proportioning of the values of resistors 69, 70, 71 and 72, connected respectively from the grid 63 to terminals 59, 32, 33 and ground. With the voltages shown, satisfactory results have been obtained when using resistances of 2.7 meg. for resistors 69 and 70, a resistance of 1.5 meg. for resistor 71, and a resistance of .47 meg. for resistor 72. Obviously other values could be employed, the chief requirement being that the resistor 71 for the cross channel input be substantially smaller than that for the direct channel input, so that a relatively larger proportion of the voltage of an input pulse, applied thereto, will be applied to the grid 63. Resistor 73, connected between the grid 63 and the commutator terminal 58, is sufficiently low that, when the corresponding commutator brush is on the grounded portion of the commutator 51, neither direct channel nor cross channel input signal will be sufficient to trigger the multivibrator, regardless of the voltage present on the gating terminal 59.

FIG. 10 shows one of the two identical gating units employed. It will be observed that this unit also involves a duo-triode tube 74 in a generally conventional multivibrator circuit, together with a gas-filled trigger tube 75 for triggering the multivibrator. In this unit the lefthand section of the tube 74 is normally heavily conducting while the righthand section is blocked. Thus the voltage appearing at the output terminal 76 is normally substantially equal to the 250-volt supply voltage. Both the tube 74 and tube 75 have a common cathode resistor 77 and the plate current normally flowing through the lefthand section of tube 74 serves to apply a sufficient positive bias to the cathode of the trigger tube 75 that no current will pass therethrough. Condenser 78, which is connected from ground to the connection between the plate 79 of the trigger tube and the grid 80 of the lefthand section of the tube 75, will therefore have a relatively high positive charge thereacross. If now a positive-going pulse is applied to the input terminal 81, the grid of the gas tube 75 will be driven sufficiently positive to cause this tube to "fire," thus rapidly discharging condenser 78. The resulting decrease in voltage on the condenser 78 will be applied to the grid 80 of the lefthand section of the multivibrator and will block this section, causing its plate voltage to rise to a relatively high value. This higher plate voltage will be applied through the voltage divider formed by resistors 82 and 83 to the grid 84 of the righthand triode section causing this latter section to become conductive. The resulting plate current flowing through the resistor 85 will produce a relatively large drop in the potential appearing at the output terminal 76. As previously set forth, this drop in potential is utilized as a gate to prevent operation of the corresponding pair of target position signal generating units by a direct channel signal when a cross channel signal is present.

Tube 74 will remain in this condition until such time as is required for condenser 78 to again be charged, through resistor 86, to a sufficiently high value to again cause the lefthand section of the tube 74 to become conductive. In the present case, the values of this resistance and condenser are so chosen that the gating pulse will have a duration of substantially 115 milliseconds. Thus the gating unit, when triggered, will maintain the associated pair of target position signal generating units insensitive to direct channel input for slightly more than one full cycle and, if the gating unit itself is triggered at least once each

cycle, will continuously maintain the associated target position signal generating units insensitive to such direct channel input.

FIG. 11 shows one of the trigger tubes and error signal generating units shown in FIG. 8, all of which are identical. As will be apparent by a comparison of this figure with FIG. 10, a somewhat similar multivibrator circuit is employed, differing primarily in the fact that a control relay serves as the plate load of the normally blocked righthand section of the multivibrator tube 87, and in the use of a conventional triode 88 in place of the gas-filled tube 75 employed in the gating unit. While a gas tube could be employed in this circuit, it is unnecessary in view of the fact that the pulses applied to the input terminal 89 of the trigger tubes will always be of sufficient duration to insure substantially complete discharge of the timing condenser 90 employed therein. As in FIG. 10, the lefthand section of the tube 87 is normally conducting and, upon triggering by the trigger tube 88, this section is blocked and the righthand section becomes conductive until such time as the condenser 90 has again been charged through the resistor 91 to a value sufficiently high to restore the tube 87 to its normal condition.

When the righthand section becomes conductive, the plate current flowing through relay coil 92 will energize this coil and cause it to actuate its movable contact arms 93 and 94, swinging them downwardly into contact with their lower terminals 95 and 96. As with the gating multivibrator, resistor 91 and condenser 90 are so chosen as to maintain the relay energized for about 115 milliseconds. Contact 95 is connected to an interlock terminal 97 which, as is shown in FIG. 8, is connected by lead 47 to an interlock control terminal 98 of the error signal generating unit for the opposite direction. Terminal 98 on each of these units, is connected to the movable contact arm 94 of the associated relay and, in the normal de-energized condition of the relay, is connected through the contacts 94 and 99 with a source of positive voltage 100. The arrangement is the same for each of the error signal generating units and when, for example, the relay 92 of the Left error signal generating unit is energized, a direct connection is made from the source of voltage 100 on the Right error signal generating unit through its contacts 94 and 99 and terminal 98, thence through lead 47 to the interlock terminal 97 on the Left error signal generating unit, thence through stationary contact 95 and movable contact 93 of this Left unit to its output terminal 101. The resulting voltage at terminal 101, which constitutes the output signal from the unit, is applied, as previously described, through the lead 43 to the azimuth servo unit 4 to cause operation of the latter to swing the sighting axis to the left. It will also be seen that, if the Right error signal generating unit is now also energized, it will open the circuit at its interlock contact 94, thus interrupting the output signal from the Left error unit. Similarly, the interlock contact 94 of the Left error unit will open the output circuit for the Right error unit, so that no voltage will appear at the output of either of these units when both are energized.

Operation of the present tracking system will best be understood by considering certain situations that might be encountered in actual use. For example, let us assume that the sighting apparatus is adjusted so that its sighting axis 19 is aimed directly at the target, as shown in FIGS. 2 and 3. Starting with the position illustrated in FIG. 3, wherein the image or scanning spot 14 is just sweeping across the lower arm of vertical sensing element 13, a sensing signal will be generated by the sensing element 13, will pass through the diode 24 and be amplified by the vertical limiting amplifier 26. The amplified signal will be applied to the direct channel input terminals 32 of the Up and Down target position units 30 and 31 and to the cross channel input terminals 33 of the Left and Right target position units 28 and 29. This pulse

will also be applied to the horizontal gating unit 49 which, as previously described, will immediately lower the voltage applied to the gate terminal 59 of the Left and Right target position units. At this instant commutator 51 will be in such a position that only Down brush 57 will be resting upon the insulated portion 52 thereof, the remaining brushes 54, 55 and 56 serving to ground the commutator terminals 58 of the Left, Right and Up target position units. As previously described, when the commutator terminal of a target position unit is grounded, that particular unit will be insensitive to signals applied to either of its input terminals 32 and 33. Thus the only target position unit that will be triggered will be Down unit 31, this unit being triggered by the vertical sensing signal appearing at its direct channel input terminal 32. The resulting positive-going target position signal appearing at the output of Down position unit 31 will cause trigger tube 38 to fire, in turn starting the operation of the Down multivibrator 87 of the error signal generating unit 42 and energizing the Down relay 92 thereof. As previously described, upper movable contact point 93 of this relay will swing downward to complete a circuit to the source of voltage 100 present on the Up error signal generating unit 41 and this voltage will therefore appear at the Down output terminal 101 and be applied through the lead 46 to the Down terminal on the elevation servo 5, starting the latter in operation to shift the sighting axis downwardly. As will later be clear, this Down output signal will, however, only exist for slightly more than one-tenth of a second and its effect can be therefore ignored.

As the scanning spot 14 then moves across the lefthand end of horizontal sensing element 12, this latter element will also generate a sensing signal which will be applied through the associated diode 25 and amplifier 27 to the direct channel input terminals of the Left and Right target position units and to the cross channel terminals 33 of the Up and Down target position units. This same sensing signal will also trigger the vertical gating unit 50 which will thereupon generate a gating pulse which, applied to the gate terminals 59 of the Up and Down target position units, will render these units insensitive to direct channel input for slightly more than one cycle.

At this time, commutator 51 will have rotated to the position illustrated in FIG. 8 wherein only the left brush 54 is on the insulated portion. Consequently the only target position unit that might be responsive to input signals would be the Left target position unit 28. However, the horizontal gating unit 49, which was triggered by the previous vertical sensing signal is still in operation and will prevent operation of the Left target position unit in response to the horizontal sensing signal applied to its direct channel input terminal 32. Thus none of the target position units will be actuated at this time.

A pulse from the vertical sensing element 13 will again be generated when the scanning spot 14 traverses the upper end of this element, but it can readily be seen that the only effect of this pulse will be to again trigger the horizontal gating unit 49 and to thus maintain it in operation for another cycle. Similarly, when the spot 14 crosses the righthand end of element 12, the only effect will be another triggering of the vertical gating unit 50. Thus as the spot continues to rotate, it will alternately cause the triggering of the horizontal and vertical gating units, twice each scanning cycle, and will thereby maintain all of the target position units insensitive to direct signals. As a result, so long as the condition illustrated in FIGS. 2 and 3 exists, no further energization of any of these units will occur. As previously mentioned, shortly after spot 14 has completed its first cycle the Down error signal generating unit 42 will time out, de-energizing its relay 92, and interrupting the voltage applied to the elevation servo 5.

Considering now the condition illustrated in FIGS. 4

and 5, wherein the sighting axis is assumed to be directed somewhat below and to the right of the target, the path 17 traversed by the scanning spot 14 will intersect but three of the four arms of the cross, as clearly indicated in FIG. 5. To assist in understanding the operation, the sectors during which each of the target position signal generating units is ungrounded (and therefore capable of responding to input signals) is designated in FIG. 5 by the arcuate arrows labeled U, R, D and L respectively. Again starting at the instant when the spot 14 is at the extreme lowermost portion of its path of travel, the first pulse will occur as it traverses the lower end of vertical sensing element 13 as indicated at 102. At this time both the Left and Down target position units will be ungrounded and the resulting signal from the vertical sensing element 13 will be applied to the direct channel input 33 of the Left unit 28. At the same time this pulse will also trigger the horizontal gating unit 49 rendering the Left and Right position units 28 and 29 insensitive to direct channel input for the succeeding cycle. However, the cross channel input to the Left position unit 28 will trigger this unit, which, as previously described, will cause actuation of the Left error signal generating unit 39 to produce a Left output signal at its output terminal 101 to cause operation of the azimuth servo 4 to shift the sighting axis to the left. Likewise, the direct channel input signal applied to the Down position unit 31 will trigger this unit and cause the Down error unit 42 to produce an output voltage initiating Down operation of the elevation servo.

The next pulse will occur as the spot 14 traverses the lefthand arm of the horizontal sensing element 12 as indicated at 103. At this time both the Left and Up target position units will be ungrounded and therefore capable of responding to input signals. However, the horizontal gating unit 49, which was previously triggered by the pulse from the vertical sensing element 13 will prevent a retriggering of the Left unit by the direct channel signal from element 12. The horizontal sensing signal applied to the cross channel input terminal of the Up position unit 30 will, however, trigger this unit to cause in turn the energization of the Up relay in the Up error signal generating unit 41. Thus at this time both the Up and Down relays will be energized and, as previously described, each will be prevented by the other from producing an output voltage. Thus the Down signal, which was previously applied to the elevation servo, will be interrupted and, since it will have lasted but a relatively small fraction of one cycle, its effect can be ignored.

As the spot 14 then moves across the upper arm of vertical sensing element 13 as indicated at 104, a vertical target sensing signal will once again be generated. At this time only the Left and Up position units are ungrounded. However, operation of the Up position unit 30 is prevented due to the fact that the vertical gating unit 50 is still in operation, preventing response of the Up unit to direct signal input. Moreover, the Left position unit 28, while it is ungrounded and would therefore normally be responsive to cross channel input, will not yet have timed out from its previous triggering, so that it will also be unaffected by the application of the vertical signal to its cross channel terminal 33. Thus the only effect of this vertical sensing signal will be to retrigger horizontal gate 49.

As the spot once again moves around to the position indicated at 102, at which time the Left and Down units will again be ungrounded, the vertical sensing signal appearing at the cross channel input terminal of the Left position unit 28 will once again trigger this unit, the output pulse therefrom serving to again discharge the condenser 90 of the error signal generating unit 39 so as to maintain this unit in operation for at least another full cycle. The vertical pulse applied to the direct channel input of the Down position unit 31 will, however, be ineffective to cause operation of this latter unit since the

vertical gating unit 50 will still be energized, and will thus render unit 31 insensitive to direct channel input.

Shortly after the spot 14 has passed the position 102, the Down error unit 42 will time out, dropping its relay and completing the connection between the voltage source 100 thereon and the output terminal 101 of the Up error unit 41. Thus, at this time, an Up signal will be applied to the elevation servo 5. As can be shown, subsequent pulses from the vertical and horizontal sensing elements will maintain both the Up relay and the Left relay energized, and the sighting axis will therefore be shifted leftward and upward in such direction as to decrease the sighting error.

From the above it can be seen that so long as cross channel input signals are available, each of the target position signal generating units will be unresponsive to direct channel input. This is desirable since much better tracking can be obtained, particularly where relatively large targets are involved, when cross channel signals are utilized. However, this is not always possible, and a situation wherein the direct channel input must be used to control the operation of one of the servo motors is illustrated in FIG. 6. Under the assumed conditions, the sighting axis is considerably below and somewhat to the right of the line of sight so that the scanning path intersects only the lower arm of the vertical sensing element 13 as indicated at 105. Under these circumstances, when the spot 14 reaches the point 105 (at which time the Up and Left target position units are ungrounded) the horizontal gating unit 49 will be triggered but, since only vertical sensing signals are present, it will have no effect. The vertical sensing signal applied to the cross channel input terminal 32 of the Left position unit 28 will trigger this unit to apply a Left output voltage to the azimuth servo 4, and the Up position unit 30 will be triggered by this same sensing signal applied to its direct channel input terminal 32, to cause the application of Up output voltage to the elevation servo 5 to cause Up operation thereof. It is to be noted that under the assumed conditions no pulses are generated by the horizontal sensing element 12 and therefore the vertical gating unit 50 will not be triggered so long as these conditions obtain. As a result, each time the spot 14 traverses the point 105 the Up unit 31 will be responsive to the direct channel input signals and Left unit 28 will, of course, be responsive to the cross channel input signal. Thus the Up and Left relays will both be maintained energized and the sighting axis will be shifted upward and to the left.

FIG. 7 illustrates diagrammatically the effective field of coverage of the tracking system described herein. So long as the center 18 of the scanning circle is within the area circumscribed by the line 106, one or both of the servos will be actuated in the proper direction to shift the sighting axis toward the target. It can be determined by analyses similar to those above that, when the center 18 of the scanning circle is within any of the areas indicated by reference numerals 107, 108, 109, and 110, the sighting axis will be shifted diagonally to effectively shift center 18 toward the center of the field as indicated by the arrows. When the center 18, representing the target, is in any of the sectors represented by reference numerals 111-114, but one of the servos will be actuated, causing the sighting axis to be shifted in one direction only toward the target. If the target is in any one of the small areas designated 115 or 116, for example, but one of the servos will be actuated until the target moves into the adjacent field such as 107 at which time the other servo will come into operation. Thus if the effective position of the target is in the area 115, the sighting axis will be shifted so as to effectively move the target position to the left into area 107 and then downward and to the left toward the center of the pattern.

I should be noted that, with the disclosed arrange-

ment, so long as the target lies within the sector 117, shown cross-hatched, no actuation of either of the servos will take place. In other words, as long as the target is within this sector, the sighting apparatus is considered to be "on-target." While this sector 117 may represent a rather considerable area about the target when the sighting apparatus is at a considerable distance from the target, the effective size of the area becomes smaller and smaller as the apparatus carrying the tracking system moves closer to the target and may therefore be ignored. At the same time a much simpler tracking system results, than if it were attempted to at all times maintain exact alignment.

From the above it is believed clear that a tracking system has been disclosed which is capable of tracking a given target accurately and without ambiguity and that, in the event of any appreciable misalignment between the sighting axis and the line of sight to the target, the sighting axis will be rapidly and effectively shifted to reduce the misalignment to an insignificant value. While the system disclosed is particularly well-adapted for use as a passive tracking system; that is, one which requires no radiation of energy from the tracking plane or missile and relies solely upon radiations from the target itself, it is obvious that the general principle of operation is equally well-adapted to incorporation in an active tracking system, for example, a tracking system employing radar apparatus.

Moreover, while many of the elements making up the complete tracking system have been illustrated in one particular form, it is believed obvious that many changes can be made in these elements without in any way affecting the operation of the unit adversely. Many other changes can obviously be made without departing from the spirit and scope of this invention as defined by the appended claims.

I claim:

1. In a direction determining apparatus having a pair of elongated sensing elements arranged in the form of a substantially symmetrical rectangular cross, the arms of which define perpendicularly related axes, scanning means responsive to the presence of a target within a predetermined scanning field for forming a moving scanning spot, said spot moving in a closed circular scanning path the center of which represents the target position and said path having a radius substantially equal to the length of the arms of said cross, each of said elements being responsive to the movement of the spot thereacross to generate at its output a target sensing signal, means for generating target position signals in response to target sensing signals from said elements, comprising a plurality of position signal generating units, one for each of the four directions represented by the arms of said cross, each of said units having a direct channel input terminal connected to the sensing element for the corresponding direction and a cross channel input terminal connected to the sensing element for the perpendicularly related directions, a pair of gating means, each being connected to one of said elements for generating a gating pulse in response to a target sensing signal therefrom, and connected to the pair of signal generating units for the perpendicularly related directions for rendering said pair of units insensitive to target sensing signals applied to the direct channel input terminals thereof for the duration of said gating pulse, and commutator means operable in timed relation to the scanning motion of said spot for selectively rendering said units responsive and unresponsive, in predetermined sequence, to target sensing signals applied to their input terminals, said commutator means and said gating means being so arranged that at any time throughout the scanning cycle at least one of said units will be responsive to signals applied to its cross channel input terminal and, in the absence of such cross channel signals, will be responsive to signals applied to its direct channel input terminal.

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2. Apparatus as set forth in claim 1, wherein said gating pulses have a duration equal to at least one complete scanning cycle whereby said units will only be responsive to direct channel input signals in the absence of cross channel input signals during the preceding cycle.

3. Apparatus as set forth in claim 1, including an error signal generating means corresponding to and controlled by the output from each of said position signaling units for generating an error signal indicating displacement of the intersection of said sensing elements 10

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from the center of said scanning path in the corresponding direction.

4. Apparatus as set forth in claim 3, wherein each of said error signal generating means includes interlock means connected to the error signal generating means for the opposite direction, so that operation of both at the same time will prevent either from producing an error signal for a predetermined time interval.

No references cited.