

Feb. 9, 1965

P. M. KNAPP
METHOD TO ADJUST PHOTOELECTRIC TELESCOPE TO
RESPOND TO CONSTANT OBJECT SIZE

3,169,191

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2 Sheets-Sheet 1

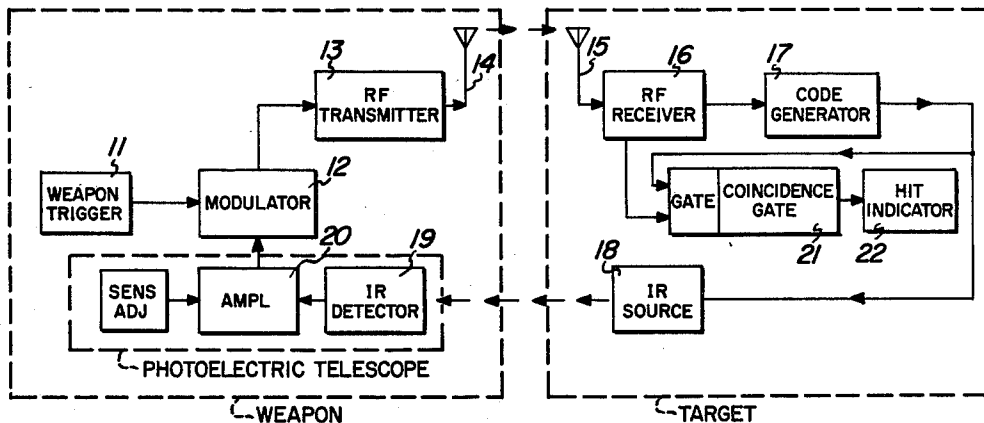


FIG. 1

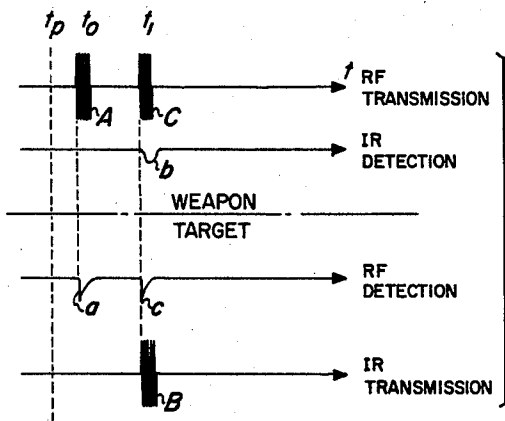


FIG. 2

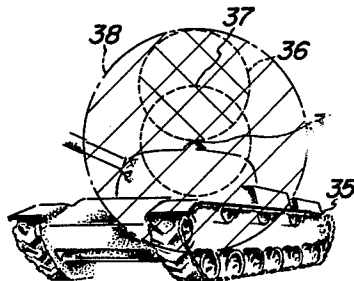


FIG. 4

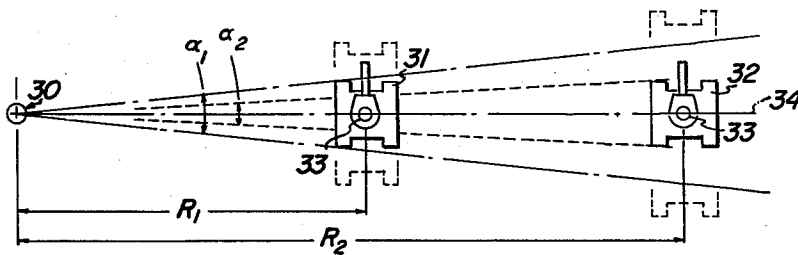


FIG. 3

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Fig. 5

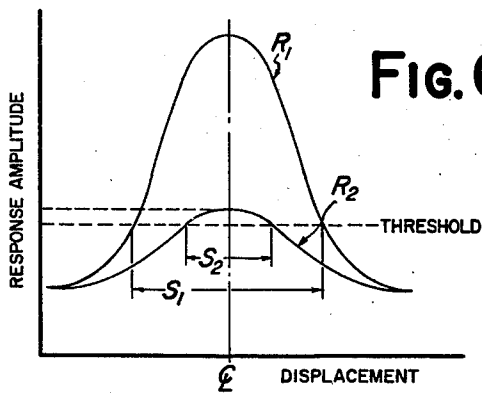
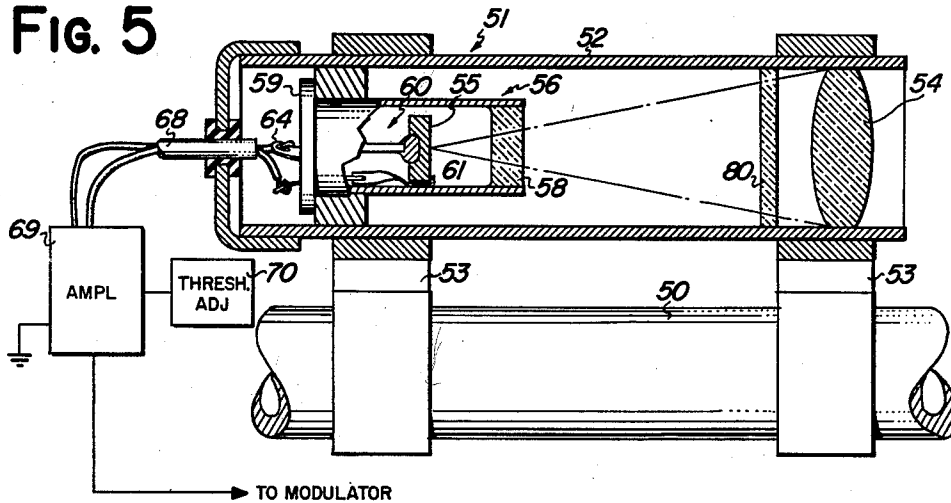


Fig. 6

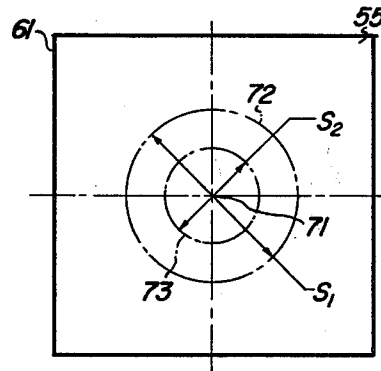


Fig. 7

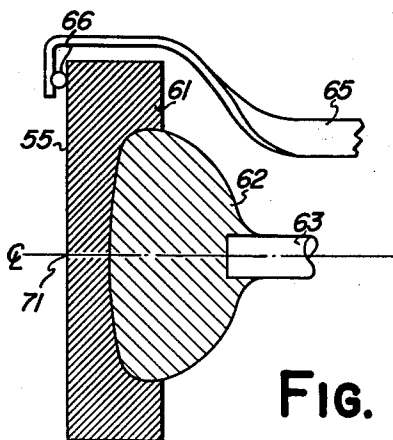


Fig. 8

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METHOD TO ADJUST PHOTOELECTRIC TELESCOPE TO RESPOND TO CONSTANT OBJECT SIZE

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2 Claims. (Cl. 250-211)

This invention relates generally to photoelectric telescopes, and more particularly to the light responsive element in such telescopes.

Co-pending application Serial No. 73,777, filed December 5, 1960 and assigned to the same assignee as this application, discloses a "Hit Indicator" system for use in training personnel in the use of weapons. Such system links a weapon with all targets by the use of an RF link, and the target at which the weapon is pointed by an IR link. The target is provided with an IR source which is caused to flash by an RF interrogation signal from the weapon. A photoelectric telescope at the weapon will "see" the flash only if the weapon is pointed at the target. One of the problems associated with this system arises from the fact that the object size of the telescope is a function of target range. That is to say, doubling the range increases the area of the field of view by four times. This means that at close range (small object size) the weapon must be pointed directly at the target if the telescope is to see the flash, while at increased range (large object size) the weapon may be considerably misaligned with the target and still see the flash.

It is therefore an object of this invention to provide a photoelectric telescope wherein the object size can be made substantially independent of target range over an interval of range so that the maximum allowable aiming error decreases with increasing target range. It is a further object of this invention to provide a photoelectric telescope wherein the object size is controlled by selective use of the output of the light responsive element in the telescope.

Briefly, the photoelectric telescope includes the optical portion which focuses light on the light responsive element, an alloy junction photodiode is the last mentioned element, an amplifier for amplifying the output of the photodiode, and a sensitivity adjustment for the amplifier. An alloy junction photodiode has a sensitive surface such that the amplitude of the output due to light being focused on a point on such surface is a function of the displacement of the point from the center of the sensitive area. By controlling the level of input to the amplifier which must be exceeded in order to obtain an output, control is exercised over the displacement, from the center of the sensitive area, of the point upon which light is focused that causes the diode to produce an amplitude equal to the sensitivity of the amplifier. The locus of such displacement is, in effect, the image size of the telescope, and through the optics, defines the object size. Thus, control of the sensitivity of the amplifier actually controls the object size.

If the response of the photodiode as a function of displacement is plotted at two values of range of a light source of constant intensity, it is possible to select a value of amplitude at which the ratio of the interval over which each response exceeds the selected value of amplitude (e.g., the ratio of the image sizes) is inversely proportional to the ratio of the ranges. If the selected value of amplitude is made the sensitivity level of the amplifier, the object size at both ranges will be the same. In this manner, the object size in the interval of ranges selected remains substantially uniform.

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Still other objects, features and attendant advantages will become apparent to those skilled in the art from a reading of the following detailed description of one preferred embodiment and mode of practice of the invention, taken in conjunction with the accompanying drawings wherein:

FIGURE 1 is a block diagram of an over-all "Hit Indicator" system utilizing an RF link and an IR link.

FIGURE 2 is a signal-time diagram for the system shown in FIGURE 1.

FIGURE 3 is a schematic which indicates how the angle subtended by a target of constant size decreases with range.

FIGURE 4 represents a target at a certain range showing the locus of points which defines an area within which the point of aim must lie for the photoelectric telescope to have an output.

FIGURE 5 shows a photoelectric telescope mounted on the barrel of a weapon.

FIGURE 6 is the amplitude response of the photodiode taken along the center line of the sensitive surface of the photodiode of FIGURE 7.

FIGURE 7 is a top view of the sensitive area of an alloy junction photodiode.

FIGURE 8 is a sectional view taken along the center line of the photodiode of FIGURE 7 and showing the leads attached thereto.

Reference is now made to FIGURE 1, which shows a hit indicator system 10 to which the photoelectric telescope of this invention is adaptable. In operation, the weapon trigger 11 is pulled when the firer believes he has the target properly aligned with the weapon. This actuates modulator 12 which turns on RF transmitter 13 causing RF pulse A to be transmitted omnidirectionally from antenna 14. Pulse A is received at antenna 15 of each target and is detected in receiver 16 as pulse *a* coincident in time with pulse A. Pulse *a* triggers code generator 17 which causes IR source 18 to flash at time t_1 , a predetermined time subsequent to time t_0 . Each target has its own time interval, $t_1 - t_0$. If the weapon is pointed at a target, IR pulse B is detected by IR detector 19 at the weapon as pulse *b* and amplified in amplifier 20. Pulse *b* causes modulator 12 to pulse transmitter 13 producing at t_1 an RF pulse C which is radiated omnidirectionally from antenna 14. This pulse is detected at each target by receiver 16 as pulse *c* coincident in time with the flash designated B from the target at which the weapon is pointed. Thus, the pulse *c* from the receiver is coincident with the pulse out of generator 17 only if the weapon is pointed at the target. The outputs of the receiver and generator are compared at 21, and if in coincidence, hit indicator 22 is actuated. The time interval $t_1 - t_0$ is controlled by the setting of code generator 17 so that a number of targets may be accommodated, each target having a different time interval associated therewith. Thus, while pulling the trigger at 11 causes the IR source at each target to flash, only that target at which the weapon is pointed will receive an RF pulse coincident with its IR flash. The above description of the hit indicator system is by way of setting forth the environment within which the photoelectric telescope of the invention may operate. Since such system forms no part of this invention, no further description is believed to be necessary.

Reference is now made to FIGURE 3 which schematically illustrates the basic difficulty with the photoelectric telescope. Point 30 represents the eye of an observer looking at target 31 a distance R_1 away, and target 32 a distance R_2 away. Targets 31 and 32 are identical, and the angle subtended by target 31 is α_1 and by target 32 is α_2 . Angle α_1 is greater than angle α_2 . Assume now that each target has an IR source 33 mounted thereon. It is obvious that if the field of view of the observer is α_1 ,

movement of target 31 between the limits shown in broken lines in FIGURE 3 is permitted without source 33 passing outside the field of view. However, at range R_2 and the same angle α_1 , it is obvious that target 32 may have a much larger movement before source 33 passes outside the field of view. Only if the field of view were restricted to the angle α_2 would target movement at range R_2 be the same as that at range R_1 before the source passes out of the field of view.

Assume now that center line 34 is the optical axis of a photoelectric telescope that is bore sighted with a weapon. It is apparent that with line 34 fixed, if target 31 were anywhere between the limits shown in FIGURE 3, the flash of source 33 would be detected. This is the same as saying that the weapon may be incorrectly aimed within plus or minus α_1 degrees of center line 34 and still detect a flash. The latter point is illustrated in FIGURE 4, which shows tank target 35 having light source 33 atop the turret. Circle 36 represents the field of view (object size) of the telescope with center 37 being the optical axis of the telescope. Circle 36 just includes source 33. Circle 38 represents the envelope of the area swept out by circle 36 as the latter is rotated around the source 33. In other words, the cross-hatched area of circle 38 represents the vulnerable area (area within which a hit is indicated) of target 35. Unless circle 36 can be kept constant with range, the vulnerable area of target 35 increases at the range of target 35 increases.

To maintain the object size substantially independent of range, the photoelectric telescope of FIGURE 5 can be used. In FIGURE 5, the barrel of a weapon is indicated at 50, and the telescope at 51. The telescope includes tubular housing 52 rigidly connected to barrel 50 by clamps 53. The forward end of housing 52 contains objective lens 54, and at the focus of this lens is the sensitive surface 55 of photodiode assembly 56. One end of tube 57 of assembly 56 is closed by glass seal 58, and the other end by plug 59. Mounted inside tube 57 is alloy junction photodiode 60 which includes an n-type bar 61 of semiconductive material with a p-type alloy pellet 62 alloyed thereto on the side remote from surface 55. Alloy junction photodiodes are well known, and an example of such a diode is shown and described on page 10-13 in Handbook of Semiconductor Electronics, edited by L. P. Hunter, published by McGraw-Hill Book Company, Inc., 1956.

Lead 63, in the form of a rigid rod, is connected to pellet 62 and extends through plug 59 and ends in terminal 64. Lead 63 serves to rigidly support the diode. Lead 65 is in the form of a flat bar that is ohmically connected to face 55 at 66 adjacent one edge of bar 61. Connection 66 is remote from the effective portion of sensitive area 55. Lead 65 passes through plug 59 and ends in terminal 67. Lead 68 connects terminals 64, 67 to amplifier 69, which is compatible for use with photodiode 60. Amplifier 69 has an adjustment 70 which controls the sensitivity level of the amplifier. Thus, for a given setting of adjustment 70, there is no output from the amplifier except when the amplitude of the output from photodiode 60 exceeds the sensitivity, and the amplifier with its sensitivity adjustment thus serves also as a selectively variable threshold signal control means or gate.

The section of the photodiode shown in FIGURE 8 is greatly enlarged. However, for a reasonable sized objective lens, the circle of confusion on surface 55 of base bar 61 can be made as small as 0.001" in diameter with the result that the effective sensitive area (surface 55) can be made over 3600 times larger than the area of the circle of confusion. Using a point source, the image of the source can be made to traverse the sensitive surface, passing through the center 71 of the surface, at which point the response is a maximum. The response of the photodiode as a function of the displacement from the center of the sensitive area of the image of a point source is shown in FIGURE 6 for ranges R_1 and R_2 . The source has a

constant intensity output and the difference in the peak amplitudes of the responses is due to the decrease in intensity of radiation reaching the sensitive surface as the source changes range.

If adjustment 70 is set so that the sensitivity of the amplifier is at a_t volts, there will be no output from the amplifier unless the output of the photodiode exceeds a_t volts. As shown in FIGURE 7, locus 72 is an equipotential line of a_t volts for the response of a point source at a range R_1 , and locus 73 is an equipotential line of a_t volts for the response of a point source at a range R_2 . Thus, diameter S_1 is really the image size of an object at range R_1 , and S_2 is the image size of an object at range R_2 . It should be noted for a given sensitivity setting, the image size generally decreases with range. If the decrease in image size is properly correlated with range, the object size can be made independent of range.

For a simple telescope, the image size is related to the optical size as follows:

$$O.S. = \frac{I.S. \times R}{F.L.}$$

where: O.S. is the object size, I.S. is the image size, R is the object range and F.L. is the focal length. Applying this to the photoelectric telescope, it is seen that the ratio of object sizes at two ranges is:

$$\frac{O.S._1}{O.S._2} = \frac{I.S._1 \times R_1}{I.S._2 \times R_2}$$

If the object sizes are to remain constant, their ratio is unity. Hence, if S_1 is the image size at range R_1 , and S_2 is the image size at R_2 :

$$\frac{S_1}{S_2} = \frac{R_2}{R_1}$$

The voltage a_t is selected to satisfy the last defined relationship. That is, the sensitivity of the amplifier is adjusted until the ratio of the intervals of displacement over which each response exceeds the sensitivity is inversely proportional to the ratio of the ranges at which the responses are obtained. As used herein, the term "interval of displacement for range R_1 over which the response exceeds the sensitivity" means S_1 , the diameter of circle 72.

It should be understood that unless the response curves for the photodiode for ranges in the interval (R_1 , R_2) intersect voltage line a_t at just the proper point, the object size will be slightly different at intermediate ranges. Experience shows that the object size increases slightly at intermediate ranges. However, proper control of the contour of the alloy junction and the elevation of surface 55 may advantageously be used to control the profile of the response curves.

Where a target is at a fixed range, a simple adjustment of the sensitivity of the amplifier will control the image size of the telescope. Through the optical relationships involved, this gives control over the object size. In this manner, the amount of angular pointing error of the telescope that achieves detection of a flash from the source can be controlled.

While other semiconductor diodes are suitable, the spectral response of a germanium photodiode peaks in the infrared region (about 1.4 microns) making this type of diode particularly well suited for use as outlined above. To this end, infrared filter 80 may be interposed between the objective lens 54 and the photodiode. This serves to prevent saturation of the photodiode due to background light. The rapidity with which a germanium diode follows light of fluctuating intensity makes such a diode well suited for use where the flash is of short duration.

While a simple telescope is shown here, it is obvious that the method disclosed herein could be used, in any optical system. Furthermore, the photoelectric telescope per se has other uses than in the system shown in FIGURE 1.

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While the invention has been described with reference to one particular illustrative embodiment and mode of practice, it will be apparent to those skilled in the art that various modifications and improvements may be made without departing from the scope of the invention. Accordingly it is to be understood that the invention is not to be limited by the specific illustrative embodiment and described manner of practice specifically set forth herein, but only by the scope of the appended claims.

What is claimed is:

1. A method for maintaining object size substantially independent of range in a photoelectric telescope that includes an alloy junction photodiode for producing an output when light is focused on the sensitive area thereof, an amplifier for amplifying the output of said photodiode, and a sensitivity adjustment for the amplifier for preventing the latter from having an output except when the output of said photodiode exceeds the value of the sensitivity comprising the steps of: focusing light from a source of constant intensity on the sensitive area of the photodiode when located at two ranges and obtaining for each range the response of the photodiode as a function of displacement on said sensitive area of the image of said source from the center of said sensitive area, and adjusting the sensitivity of the amplifier until the ratio of the intervals of said displacement over which each response exceeds the sensitivity of said amplifier is inversely proportional to the ratio of the two ranges.

2. A method for maintaining object size substantially independent of range in a photoelectric telescope that in-

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cludes an alloy junction photodiode for producing an output when light is focused on the sensitive area thereof, signal control means connected to the output of said photodiode, and a sensitivity adjustment for the signal control means for preventing the latter from having an output except when the output of said photodiode exceeds the value of the sensitivity comprising the steps of: focusing light from a source of constant intensity on the sensitive area of the photodiode when located at two ranges and obtaining for each range the response of the photodiode as a function of displacement on said sensitive area of the image of said source from the center of said sensitive area, and adjusting the sensitivity of said signal control means until the ratio of the intervals of said displacement over which each response exceeds the sensitivity of said amplifier is inversely proportional to the ratio of the two ranges.

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