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This invention relates to infra-red detection systems generally, and more particularly to infra-red systems for detecting ballistic missiles within a scoring area.

Training in the accurate firing of weapons includes the use of appropriate training techniques under closely simulated combat conditions. The gunnery trainee fires at moving targets which vary widely in distance. Evaluation of training performance is accomplished with the aid of a hit-indicating system. Targets presently in use are constructed of selected material so arranged that the penetration of a bullet or shell initiates a signal which is transmitted by electric cable to a hit indicator located at a desired remote point.

Typical systems of this kind use electrical-conducting rubber or a laminate of metal with a non-conductive core as target material. With the rubber type, hit triggering is gained through the electrical imbalance resulting in the attached circuitry when bullet penetration takes place. In the case of the laminate, a simple circuit shorting occurs to create triggering when the target is pierced by a bullet. In another known system, mechanically-actuated targets make use of the shock effect produced by the bullet to activate a microswitch arrangement for operating a hit indicator.

Among the disadvantages of the known systems is the rapid destruction of the target and the consequent need for comparatively expensive replacements. Also, such systems require bullets or shells of limited sizes and characteristics, according to the design of the target system. In addition, the mobility of existing target systems is low.

Other types of target hit-indicators have been tested experimentally. Among these are systems employing special shells which are designed to emit signals that register upon an associated sensing device at the target. The requirement for special ammunition is a severe restriction on the practical use of such systems. Experiments have also been made with systems depending upon the interception or reflection of energy emitted from the target or from a location near the target. The disadvantages of these systems are their required bulk and consequent limitations on mobility, and the fact that these systems are complicated and expensive.

To satisfy the practical requirements of target practice on gunnery ranges, it is the primary object of this invention to provide a missile detection system that is simple, mobile and responsive to all types of missiles. Among the advantages of the system according to this invention are durability, accuracy, and the fact that there is no requirement for any type of signal to be specially radiated as an aid to missile detection. Thus the system is passive in nature.

Another object of this invention is to provide a missile detection system which indicates a hit if any missile passes through a target having a shape simulating objects encountered in warfare.

Another object is to provide a low cost missile detection system which is not subject to destruction by continual use.

Briefly stated, these objects are accomplished in a system comprising a plurality of infra-red detectors together with means to convert simultaneous detection of infra-red energy by all of said detectors into an intelligible signal representing a hit upon the target. Each detector is constructed so that it is responsive to infra-red energy arriving from predetermined angles, thus establishing a sensing pattern for each detector. The detectors are placed relative to one another and are individually oriented so that their sensing patterns intersect in space to define a missile sensing zone of predetermined shape. Missiles passing through this missile sensing zone are detected simultaneously by all of the infra-red detectors to provide a hit indication.

These and other features of the invention will become apparent from the following detailed description thereof, taken in conjunction with the several FIGURES of the drawings, in which:

FIG. 1 is a view of a typical installation of an infra-red missile detection system built in accordance with the invention, showing the disposition and arrangement of three infra-red detecting means on a carrier;

FIG. 2 illustrates the intersecting sensing patterns of the three detectors in FIG. 1;

FIG. 3 is a block diagram showing the main components of an infra-red missile detection system in accordance with the invention;

FIG. 4 is a cross-sectional view of one infra-red detector; and

FIG. 5 is a partial isometric view of the infra-red detector showing the relationship of its functional elements.

Referring now to FIG. 1, there is shown three infra-red detectors 11, 12 and 13 mounted on a remote-controlled carrier 14. In the example shown, the carrier 14 is a flat bed vehicle and the detectors 11, 12, 13 are supported on a guard rail 14a positioned below the surface of the bed. The vehicle is self-propelled and may be controlled by radio telemetry from a remote position. The silhouette of the vehicle is sufficiently low so that all elements thereof including the detectors and wheels may be protected fully by range bunkers.

A visible target 15 of trapezoidal shape is attached to a carrier 14 to extend vertically above the bed thereof for the purpose of presenting the target area to the gunnery trainee. Visible target 15 is designed to survive repeated penetration by missiles and is easily and inexpensively replaced.

In order to score hits, the target area is also defined optically by the three detectors. Infra-red detectors 11 and 12 are each arranged to have narrow rectangular cones of infra-red sensitivity. Infra-red detectors 11 and 12 are placed adjacent the front corners of the bed of the carrier 14 on either side of the missile sensing zone and they are oriented so that their narrow rectangular cone sensing patterns, which are projected in the vertical plane, intersect in front of visible target 15. The sensing patterns of infra-red detectors 11 and 12 are therefore oriented at right angles to the missile line of flight. As best seen in FIG. 2, the sensing patterns 11A and 12A, as seen looking directly into the target area, represent the response areas of detectors 11 and 12, these patterns defining the inclined edges of the trapezoidal target zone.

Infra-red detector 13 has a wider rectangular cone pattern than infra-red detectors 11 and 12. Infra-red detector 13 is placed at the rear of the vehicle beneath visible target 15 and is oriented so that its wide rectangular cone sensing pattern 13A, projected forwardly, intersects part of the intersection defined by the vertically sensing patterns of infra-red detectors 11 and 12. Sensing patterns 13A defines the upper and lower edges of the trapezoidal target zone. The sensing pattern 13A of infra-red detector 13 is oriented nearly in line with the missile path to visible target 15.

As evident in FIG. 2, the intersections of the sensing patterns of infra-red detectors 11, 12 and 13 act to erect
a missile sensing zone 15A in front of visible target 15. The sensing patterns of the three infra-red detectors are so predetermined, and the arrangement of the three infra-red detectors is such, that the missile sensing zone has the trapezoidal shape matching that of visible target 15. It will be understood that this shape can be adjusted as desired by varying the shape of the sensing patterns.

Missiles which follow a path to strike visible target 15 must pass through the missile sensing zone 15A. Missiles which would miss visible target 15 do not pass through the missile sensing zone. Since in passing through the zone the missile intercepts simultaneously the sensing patterns of all three detectors, the coincident response of the three detectors may be used to provide a hit indication.

The blocks of FIG. 3 represent electrical components of one preferred embodiment of an infra-red missile detection system in accordance with the invention. Infra-red detectors 11, 12 and 13 each contain a sensing element, such as a lead sulfide photoconductive layer, which functions as an electrical resistance that is varied by the influence of infra-red energy. The static resistance of the sensing element in each infra-red detector is determined by the area of the sensing element. A sensing element of small area has a high electrical resistance; a sensing element of large area has a lower electrical resistance.

For example, infra-red detectors 11 and 12 each have small-area sensing elements having a resistance of approximately 1 megohm. Infra-red detector 13 has a large-area sensing element having a resistance of approximately 1/2 megohm. The small-area sensing elements of infra-red detectors 11 and 12 determine sensing patterns of narrow rectangular cones. The large-area sensing element of infra-red detector 13 determines a sensing pattern of a relatively wide rectangular cone.

The sensing elements of infra-red detectors 11, 12 and 13 are each connected in series with voltage dividers 16, 17 and 18, respectively, which consist of a voltage source and a fixed resistance approximately equal to the resistance of the sensing element. The voltage source is approximately 100 volts D.C. The variation in resistance of each sensing element caused by the influence of infra-red radiation results in a variation in voltage across the resistance of the sensing element. This variation in voltage produces a pulse which is capacitively fed from voltage dividers 16, 17 and 18 to amplifiers 19, 20 and 21, respectively.

Amplifiers 19 and 20 accommodate a range of frequencies of 500 cycles to 2000 cycles per second. The 300 cycle lower limit prevents slowly moving objects, which emit infra-red radiation and therefore are detected by infra-red detectors 11 or 12, from affecting the output of amplifiers 19 or 20. For instance, birds, aircraft, clouds, and vehicles move appreciably slower than missiles and are filtered out of the detection system by the 500 cycle cut-off in amplifiers 19 or 20.

The 2000 cycle upper limit eliminates noise above 2000 cycles while permitting voltage variations caused by missiles to pass through amplifiers 19 or 20. In this application, all missiles are expected to have speeds relative to infra-red detectors 11 and 12 which will produce voltage variations having a frequency in the 500 cycle to 2000 cycle per second range.

Amplifier 21 has a frequency range of 100 cycles to 2000 cycles per second. This lower limit of only 100 cycles is chosen because the sensing pattern of infra-red detector 13 is oriented nearly in the line of flight of missiles aimed at the target. Thus missiles take a longer time to traverse the sensing pattern of infra-red detector 13 than do to traverse the sensing patterns of infra-red detectors 11 and 12, which are oriented at right angles to the missile line of flight. In addition, the sensing pattern of infra-red detector 13 is much wider than the sensing patterns of the other two infra-red detectors, contributing to a longer traversing time by missiles. The longer the traversing time of a missile through a sensing pattern the frequency of the signal produced by the infra-red detector sensing element in response to the missile.

Another advantage in having low-frequency cut-offs in the amplifiers is the minimization of the effects of direct sunlight upon the detectors. Although sunlight is intense, it is relatively steady and may be regarded as equivalent to a D.C. infra-red source. By preventing D.C. from affecting the amplifier outputs, the background daylight level is filtered out of the system.

The pulse outputs of amplifiers 19, 20 and 21 are coupled to the inputs of an AND gate 22, which is an electrical device having an output only if all its inputs coincide. Thus pulses must be present simultaneously from all three infra-red detectors 11, 12 and 13, to produce an output from gate 22, indicating that a missile is within the area defined as the target by the intersection of the three infra-red detector sensing patterns.

The output of gate 22 is a single pulse duplicating the shape of its input pulses. The pulse from gate 22 is used to trigger a time-delay multivibrator 23, producing a relatively broad pulse which is used to initiate hit-indicating and alarm equipment. Each input pulse from gate 22 causes multivibrator 23 to produce one broad pulse. The broad pulse from multivibrator 23 is channeled through indication selector 24, which may be set to send broad pulses to smoke generator 25, to transmitter 26, or both.

Smoke generator 25, mounted with the target directly on the vehicle, emits a puff of smoke for each broad pulse from indication selector 24, thus visually indicating a target hit. The generator may be constituted by a tank of pressurized liquid titanium tetrachloride which when sprayed out as a mist forms a dense white smoke. The tank is controlled by a solenoid valve operated on command from the indicator selector such that when a hit is registered, the valve opens briefly to generate a white puff of smoke simulating a direct hit.

Transmitter 26 modulates a carrier with the broad pulses from indication selector 24 and radiates the carrier from antenna 27 mounted to be suitable for infra-red reflection. The broad pulse-modulated carrier is received by remote antenna 28, detected by receiver 29, and used to operate a hit-indicating counter 30.

Referring now to FIG. 4 showing the internal construction of infra-red detector 11, its housing is comprised of aluminum castings 31 and 32, casting 31 being cup shaped and casting 32 being in the form of a ring secured to the rim of casting 31. Supported within ring 32 is an interference filter 34 and nested within cup 31 is a spherical mirror 35. The inner surface of ring 32 is conically tapered to form a converging entrance which reduces the effects of scattered energy and light upon the infra-red detector.

Interference filter 34 is made of fused quartz and has a germanium coating 34a on the mirror side. The germanium-coated interference filter 34 may be protected from the atmosphere on both sides by coatings of silicon monoxide with no impairment of infra-red detection. The germanium coating 34a prevents all electromagnetic radiation except the infra-red spectrum from passing through. Spherical mirror 35 is preferably made of Pyrex glass and is gold-plated on the spherical surface to form a large mirror suitable for infra-red reflection. Aperture 36 in mirror 35 is provided for quality test at the manufacturer's plant.

Infra-red energy is reflected from the surface of spherical mirror 35 towards the central optical axis thereof and is thereby concentrated on a detector constituted by a form 37 and a sensing element 38 coated such as to intercept a predetermined portion of the reflected infra-red energy. The coating may be constituted by lead sulfide or any other suitable material sensitive to infra-red.
rays. Form 37 is fixedly supported centrally within cup 31 by means of a pedestal 39 projecting from a brass spider 40 whose legs are secured to ring 32, incoming energy passing through the legs. Electrical leads connected to the extremities of the sensing element may be arranged to pass along the pedestal and the spider. Sensing element form 37 is made from low sodium glass and is cut to present a section of a spherical surface to spherical mirror 35.

The contour of the area of sensing element 38 on the spherical surface form 37 determines the sensing pattern of infra-red detector 11 in that only infra-red energy falling on the area of sensing element 38 is sensed. In effect, the shape and dimensions of sensing element 38 selects for detection only predetermined angles of all infra-red energy reaching spherical mirror 35. In this application, the sensing pattern of infra-red detector 11, as determined by the shape and dimensions of sensing element 38, is that of a rectangular cone.

Sensing element 38 is positioned with respect to mirror 35 so that each angle of infra-red energy arriving through the opening 39 is reflected to the surface of sensing element 38. For each point on the surface of sensing element 38 to correspond to a particular angle of arriving infra-red energy, the surface of sensing element 38 must be concentrically curved with the surface of mirror 35, as shown in FIG. 4. However, other curvatures of sensing element 38 may be employed. If this is the case, there will be points on the surface of sensing element 38 which receive relatively broad angles of arriving infra-red energy. The effect is a loss of discrimination in the sensing pattern. Whatever the curvature of sensing element 38, the sensing pattern is determined by shaping sensing element 38 so that only predetermined angles of arriving infra-red energy are sensed.

This is done by providing a sensing element surface only at points corresponding to reflection of desired angles of infra-red energy.

Sensing element 38 may be protected from atmospheric deterioration by a plastic film such as polybutyl meth acrylate with no adverse effects upon the sensitivity of sensing element 38.

A typical hit indication occurs as follows. A missile 10 is aimed at the center of visible target 15. The trajectory of missile 10 passes through the missile sensing zone 15A defined by the intersections of the sensing patterns 11A, 12A and 13A of infra-red detectors 11, 12 and 13. Infra-red energy from the missile is sensed simultaneously by the sensing elements of infra-red detectors 11, 12 and 13. The change in the resistance of the sensing element of each infra-red detector effected by the infra-red energy is converted to a voltage variation by voltage dividers 16, 17 and 18, respectively.

The voltage variations from each voltage divider are amplified by amplifiers 19, 20 and 21, respectively. The outputs of amplifiers 19, 20 and 21 supply three inputs to gate 22. The three inputs are amplified voltage variations occurring at gate 22 output is a voltage variation duplicating the input voltage variations. The gate output voltage variation is converted into a broad pulse by multivibrator 23. The broad pulse is switched to smoke generator 25 by indication selector 24. Indication selector 24 may also be set to switch the broad pulse to transmitter 26, if desired. The broad pulse causes smoke generator 25 to emit a puff of smoke, thus giving a visual indication of a missile hit upon visible target 15.

It should be noted that if a missile passes through an intersection of only two sensing patterns, the third infra-red detector does not sense the infra-red energy from the missile. Thus there are only two simultaneous inputs to gate 22. Gate 22 produces no output voltage variation in this case.

While there has been shown what is considered to be a preferred embodiment of the invention, it will be manifest that many changes and modifications may be made therein without departing from the essential spirit of the invention. It is intended therefore, in the annexed claims to cover all such changes and modifications as fall within the true scope of the invention.

What is claimed is:

1. A passive infra-red missile detection system for scoring missiles fired at a visible target comprising a plurality of infra-red detectors arranged and disposed so that their sensing patterns mutually intersect to define a missile sensing zone in front of said target and having a form substantially matching said target, each of said infra-red detectors having means for shaping its sensing pattern, and means to convert simultaneous detection of infra-red energy by all of said plurality of infra-red detectors onto an intelligible signal representing missile penetration of said missile sensing zone.

2. A passive infra-red missile detection system for scoring missiles fired at a visible target comprising a plurality of infra-red detectors arranged and disposed so that their sensing patterns mutually intersect to define a missile sensing zone in front of said target and having a form substantially matching said target, each of said infra-red detectors having means for shaping its sensing pattern, and means to convert simultaneous detection of infra-red energy by all of said plurality of infra-red detectors onto an intelligible signal representing missile penetration of said missile sensing zone.

3. A passive infra-red missile detection system for scoring missiles fired at a visible target of trapezoidal shape comprising a plurality of infra-red detectors arranged and disposed so that their sensing patterns mutually intersect to define a missile sensing zone in front of said target and having a form substantially matching said target, each of said infra-red detectors having means for shaping its sensing pattern, said means comprising an infra-red sensing element having a predetermined shape adapted to receive infra-red energy from a curved mirror, and means to convert simultaneous detection of infra-red energy by all of said plurality of infra-red detectors onto an intelligible signal representing missile penetration of said missile sensing zone.

4. A passive infra-red missile detection system for scoring missiles fired at a visible target of trapezoidal shape comprising three infra-red detectors arranged and disposed so that their sensing patterns mutually intersect to define a missile sensing zone in front of said target and having a form substantially matching said target, each of said infra-red detectors having means for shaping its sensing pattern, said means comprising an infra-red sensing element having a predetermined shape adapted to intercept only predetermined angles of infra-red energy from a curved mirror, and means to convert simultaneous detection of infra-red energy by said three infra-red detectors into an intelligible signal representing missile penetration of said missile sensing zone.

5. A passive infra-red missile detection system for scoring missiles fired at a visible target comprising a plurality of infra-red detectors arranged and disposed so that their sensing patterns mutually intersect to define a missile sensing zone in front of said target and having a form substantially matching said target, each of said infra-red detectors having means for shaping its sensing pattern, said means comprising an infra-red sensing element having a predetermined shape adapted to intercept only predetermined angles of infra-red energy from a curved mirror, and means to convert simultaneous detection of infra-red energy by said three infra-red detectors into an intelligible signal representing missile penetration of said missile sensing zone.
red detectors, and means to convert the output of said logical circuit into an intelligible signal.

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