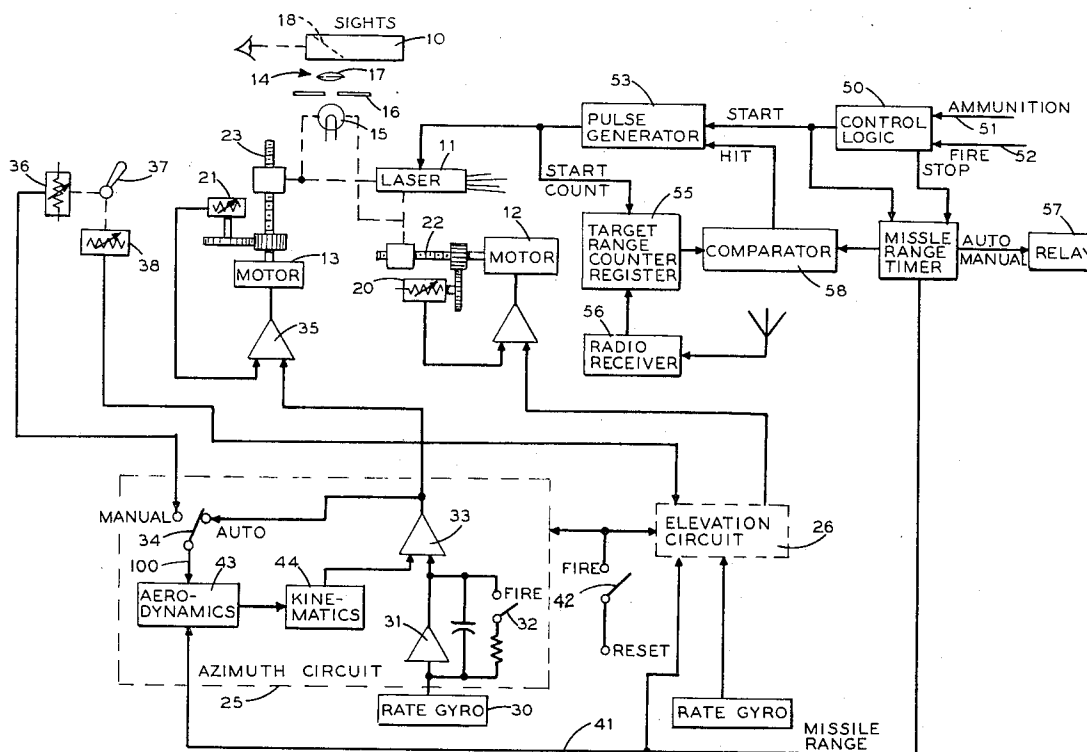
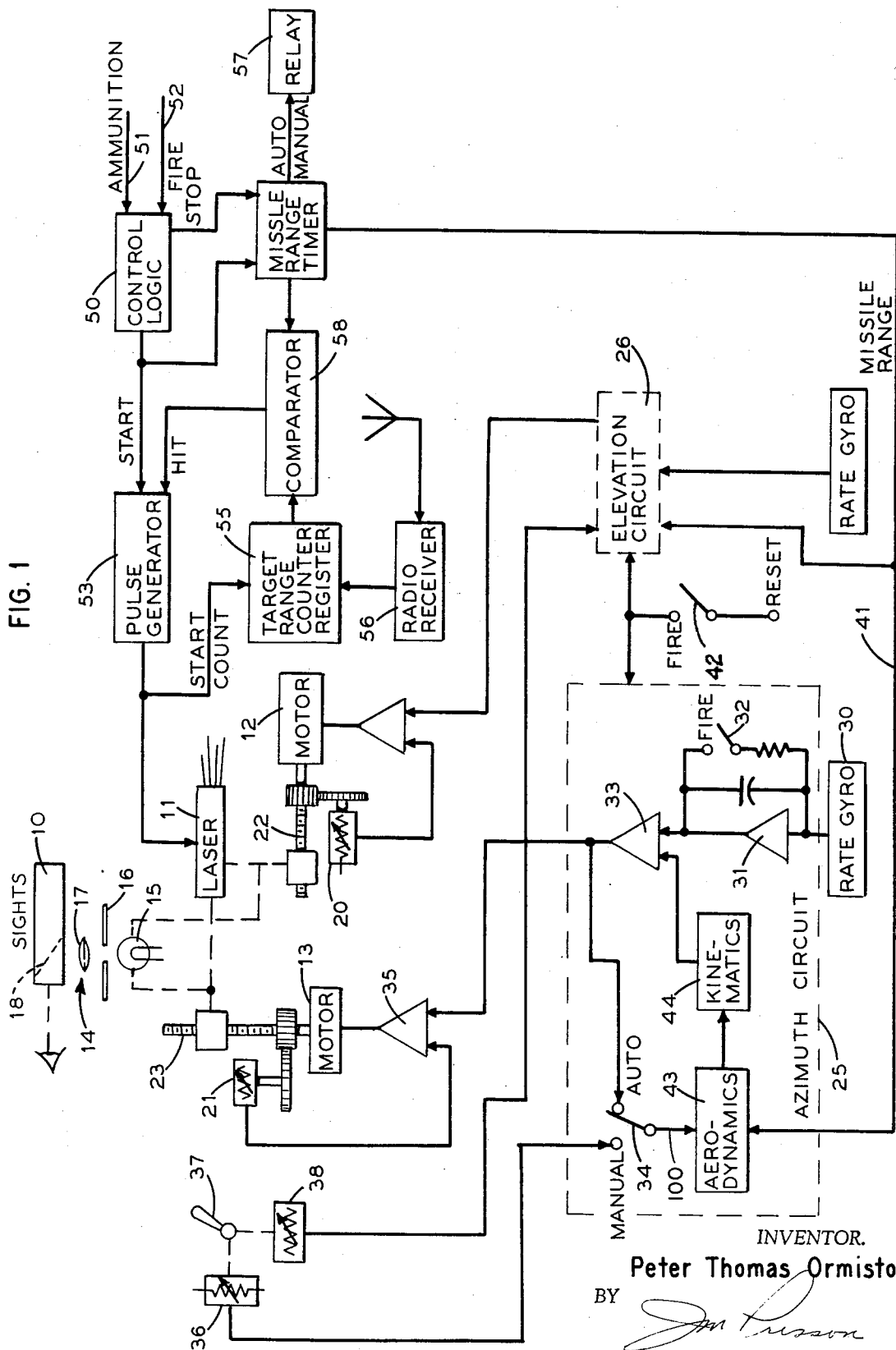


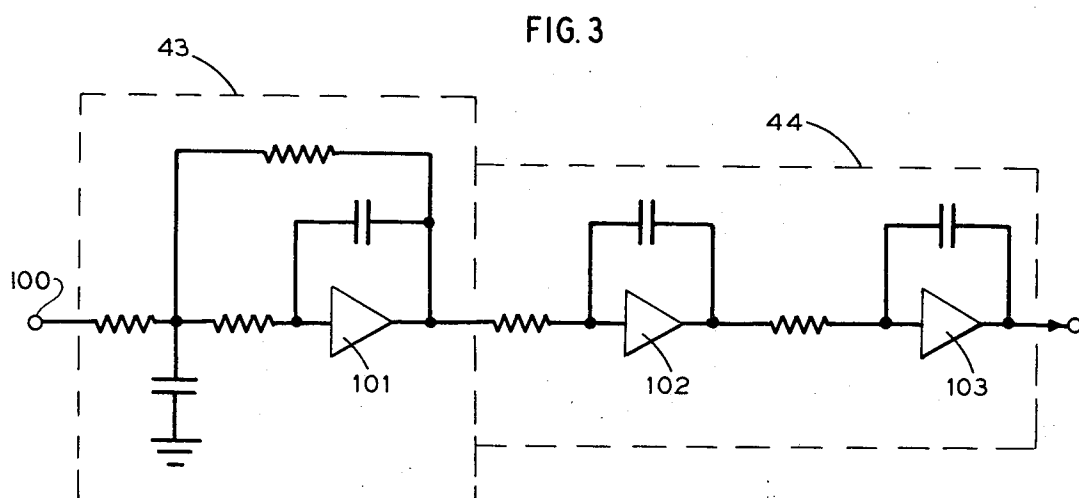
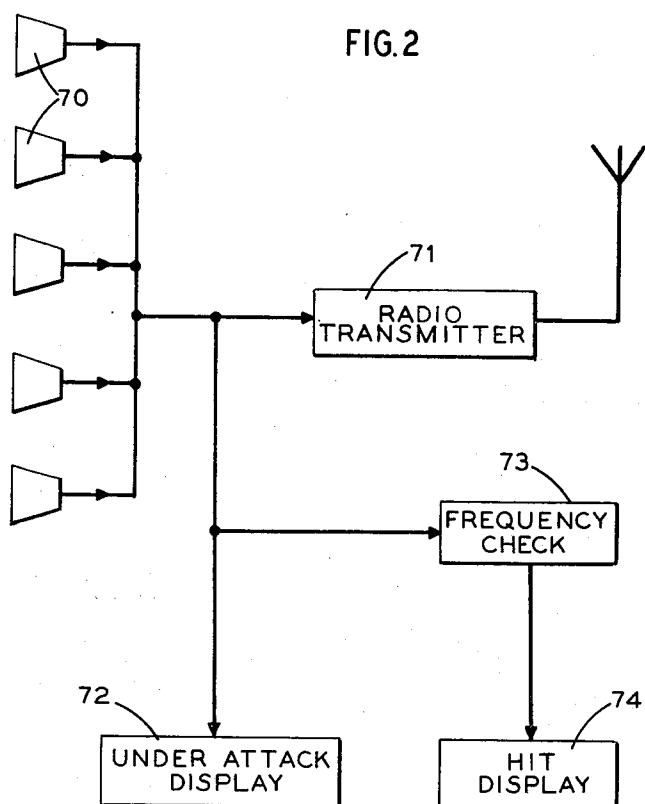
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27 Claims, 3 Drawing Figures





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WEAPON TRAINING SYSTEMS

This invention relates to a weapon training system for training a pupil in the firing and control of guided missiles.

This invention concerns improvements in and modifications of the system described and claimed in the specification of co-pending Australian Pat. Application No. 35899/68, namely, a weapon training system comprising aiming means for aiming at a target, a source adapted in operation to provide a beam of electromagnetic radiation, a linkage between the aiming means and the source for orienting the source in an orientation related to the orientation of the aiming means, a detector on the target and adapted in operation to receive the beam when the aiming means is aimed with a predetermined accuracy, and an indicator adapted to provide in operation information concerning the accuracy of the aim.

A need has arisen for a training system for training pupils in the firing and control of guided missiles, particularly of the type fired from hand-held launchers.

According to this invention in one aspect there is provided a missile launcher simulator comprising aiming means for aiming at a target, a source adapted in operation to provide a beam of electromagnetic radiation, a linkage between the aiming means and the source for orienting the source in an orientation related to the orientation of the aiming means in dependence upon a control signal, and means for generating the control signal in response to changes in the orientation of the aiming means and in response to difference information concerning the difference in the orientations of the aiming means and the source.

This launcher simulator will normally be used in combination with a target simulator comprising a detector adapted in operation to receive the beam when the source is orientated with a predetermined accuracy, an indicator being provided for indicating information concerning the accuracy of the aim.

According to this invention in another aspect, there is provided a missile launcher simulator comprising aiming means for aiming at a target, means for illuminating a small area within the field of view of the aiming means, a linkage between the aiming means and the illuminating means for positioning the said small area in the said field of view in a position dependent upon a control signal, and means for generating the control signal in response to changes in the orientation of the aiming means and in response to difference information concerning the position of the said small area within the said field of view.

In either aspect of the invention, the said difference information may be provided by manually-operated means, such as potentiometers. Alternatively, the difference information may be derived from the control signal itself.

The generating means may include means for forming a signal dependent upon the orientation of the aiming means, which may include a gyro.

The two aspects of the invention are preferably used in combination, the position of the said small area being fixed with reference to the orientation of the electromagnetic source. In such an arrangement of the position of the said small area within the said field of view is related to the difference in the orientations of the aiming means and the source.

On embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 is a block circuit diagram of a launcher simulator embodying the invention;

FIG. 2 is a block circuit diagram of a target simulator for use with the launcher simulator of FIG. 1; and

FIG. 3 is a circuit diagram of the aerodynamic and kinematic simulator circuits of FIG. 1.

The operation of the real launcher and missile which is simulated in the simulator of FIG. 1 will first be described.

The launcher includes a hollow tube or pipe which is carried by the operator on his shoulder. Sights are fixed along a line parallel with the launcher pipe and include a graticule enabling the operator to estimate small angular deviations from the sight line.

The operator first carries out an arming procedure to load the launcher. He then holds the launcher so that the center of the graticule lies on the target, for example a helicopter. The operator then presses a 'Fire' button on the launcher, whereupon the missile is fired. Correction is now required for errors in the missile's path and also for movement of the target subsequent to firing of the missile.

The operator continues to maintain the graticule accurately on the target. Included in the optical system comprising the sights is an infra-red detector consisting of a number of plates which detect infra-red radiation emitted by the missile jets. The detectors are arranged around the center line of the sights to provide an electrical output indicative of the direction and magnitude of the angular error in the path of the missile from the sight line which, as described, is kept on the target. The electrical output is then transmitted by a radio link to the missile to make a compensating alteration to the angles of the missile fins or jets.

After a time, the infra-red radiation emitted by the missile is insufficient for the infra-red detectors to provide a useful output, and error signals then have to be generated manually. This may be done by means of a pair of potentiometers positioned at right angles and operated by a single thumb-operated lever on the launcher. The operator estimates the angular error of the missile from the sight line and moves the potentiometers to a position dependent upon the estimation. The output of the potentiometers connected to the lever is then transmitted to the missile. Means are provided to indicate to the operator the moment of changeover from the automatic to the manual phase.

It is, therefore, desirable that a simulator shall be able to simulate both the automatic and manual phases of operation, although it will be appreciated that simulators may be provided which can simulate only one of the two phases. It is also desirable that the simulator should simulate correctly the response of a missile to an error signal. For example, when the missile is not far from the launcher, a small correcting movement of the missile may be sufficient to correct for a certain angular error. However, when the missile is further from the launcher, to correct for the same angular error a much larger correcting movement is required. Also the movement of the missile is underdamped; in other words, it will tend to over-correct if attempts are made to correct suddenly for large angular errors in its flight path.

The launcher simulator of FIG. 1 will now be described. The simulator appears to the operator to be substantially identical with the launcher described above which is being simulated, and includes telescopic sights 10 mounted on the launcher (not shown), a thumb-operated lever or joystick 37, and a 'Fire' button (not shown).

Also mounted on the launcher is an infra-red laser 11. The position of the laser relative to the launcher (and hence the sights) is controlled by two servo-motors 12 and 13 which respectively control the elevation and azimuth of the laser with respect to the launcher pipe by means of screws 22 and 23.

Fixed relative to the laser so as to be controlled by the servo-motors 12 and 13 is a so-called spot-injection unit 14 which generates in the sights a spot of light the position of which indicates the orientation of the laser 11 and thus represents the assumed position of the missile. The spot injection unit includes a lamp bulb 15, a diaphragm aperture 16, and a lens 17. The lamp bulb 15 is illuminated from the moment when the 'Fire' button is pressed. A half-silvered mirror 18 in the sights superposes an image of the diaphragm aperture 16 on the scene viewed directly through the sights to indicate the assumed missile position. The diaphragm aperture 16 may be variable in size, as will be described, to simulate the decrease in apparent size of a receding missile.

If a semiconductor light source or a cathode ray tube is used in place of the lamp bulb 15, a variable diaphragm aperture is unnecessary.

The angular position of the laser 11 is controlled by control signals applied to the servomotors 12 and 13 from azimuth and elevation circuits 25 and 26 respectively, which are identical. Only the azimuth circuit 25 is therefore described and illustrated in detail.

The azimuth circuit 25 includes an integrating amplifier 31 connected to the output of a rate gyro 30. A rate gyro produces an output dependent upon the rate of angular movement of the gyro relative to its mounting, which in this case is the launcher. If the rate of movement is integrated over time, the amount of angular movement from a given zero is obtained. The zero is set at the moment of firing by "uncaging" the gyro, and this is achieved by opening a switch 32 which, when closed, effectively shorts out the amplifier 31. The switch 32 is opened in response to actuation of the 'Fire' button. The output of the integrating amplifier 31 is proportional to the total angular displacement of the sights in the azimuth direction measured from the moment of firing. The output of the amplifier is applied to a summing amplifier 33.

The azimuth circuit 25 also includes an aerodynamic simulation circuit 43, the output of which is connected to a kinematic simulation circuit 44. The aerodynamic simulation circuit 43 is connected to receive an error signal dependent upon the angular difference between the orientation of the sights 10 and the orientation of the laser 11, and generates an output signal which represents the real dynamic response of the simulated missile to such an error signal, namely a signal proportional to the sideways acceleration of the missile. This signal is integrated in a kinematic simulation circuit 44 to provide a signal proportional to the angular displacement of the laser with reference to its orientation of the moment of firing.

The amplifier 33 subtracts the two input signals applied thereto. Since the output of the amplifier 31 is proportional to the total angular displacement of the sights since the moment of firing and the output of the circuit 44 is proportional to the total angular displacement of the laser since the moment of firing, the difference between these two signals is proportional to the angular difference between the orientations of the sights and the laser.

The output of the amplifier 33 is applied to a differential amplifier 35 which forms part of a servo loop including the motor 13 and a potentiometer 21 driven by the motor, the output of the potentiometer being connected to another input of the amplifier 35. When the signals applied to the inputs of the differential amplifier 35 are unequal, the motor rotates to vary the output of the potentiometer 21 until they are equal, whereupon the motor stops. The servo-motors have a fast response so as to be able to move the laser as quickly as the quickest practicable movement likely to be given to the launcher by the operator.

During the automatic phase, the input of the aerodynamic simulation circuit 43 is obtained through a switch 34 from the output of the amplifier 33. A stabilizing circuit may be included between the amplifier 33 and the switch 34 to maintain the stability of the loop. During the manual phase the input of the circuit 43 is connected by the switch 34 to a potentiometer 36 operated by the thumb lever 37. The thumb lever 37 also controls a potentiometer 38 for the elevation circuit 26. The switch 34 is operated by a relay 57, as is described below, and means are provided to indicate to the operator when the change-over takes place, as in the real launcher being simulated.

With simulating missile launchers other than hand-held types, it will usually be possible to determine the orientation of the launcher by means such as potentiometers, which may replace the rate gyro 30 and the amplifier 31.

Suitable circuits for use as the aerodynamic simulation circuit 43 and the kinematic simulation circuit 44 will now be described with reference to FIG. 3. An input 100 is connected to a first operational amplifier 101. As stated above, the signal applied to the input 100 is proportional to the angular difference between the orientations of the sights and the laser, or in other words, proportional to the angular difference between the assumed position of the missile and the position of the target. The resistors and capacitors associated with the amplifier 101 are such that the output from the amplifier 101 is proportional to the angular acceleration of the missile being simulated in response to the input signal. The aerodynamic simulation circuit 43 in fact generates an approximate solution to the second order differential equation;

$$\ddot{h} = \frac{K}{s^2 + 2\mu\omega p + p^2}$$

where:

$\ddot{h}$ = lateral acceleration

ξ = fin or jet angle

K = constant

ω = natural frequency of missile aerodynamic response

μ = damping rate of missile aerodynamic response

p = Laplace transform operator

The characteristics of the amplifier 101 are modified in accordance with the assumed instantaneous range of the missile from the launcher, information concerning the range being supplied to the circuit 43 over a line 41. The amplification factor of the amplifier 101 is made inversely proportional to the missile range.

The output of the amplifier 101 is applied to the kinematic simulation circuit 44 and is integrated in each of two further operational amplifiers 102 and 103 connected in series. The output of amplifier 103 is proportional to the angular displacement of the missile (i.e. the laser) in response to the input error signal. The circuits 43 and 44 are reset to zero at the moment of firing, by means of a switch 42 which is closed on actuation of the 'Fire' button, and the output of the amplifier 103 is therefore proportional to the total angular displacement of the laser since the moment of firing.

Additional circuits may be included within the kinematic simulation circuits 44 to simulate random flight disturbance, and crosswinds. To simulate random flight disturbances, low periodicity signals are added to the input, and to simulate crosswinds, a d.c. bias is applied to the input of the amplifier 103.

The launcher simulator of FIG. 1 also includes control and range-measuring circuits. Control logic 50 is supplied with information concerning the nature and availability of the simulated ammunition being fired, which may be obtained from a rounds counter circuit. In a simple instance the control logic comprises an AND gate of which the output is connected to the SET input of the bistable circuit. When a predetermined arming procedure has been carried out so that the launcher is assumed to be loaded, a signal is applied over line 51 to the AND gate, and, when the operator presses the 'Fire' button, the other input of the AND gate is enabled over line 52, thus setting the bistable circuit. The output of the control logic 50 is connected to a pulse generator 53 and to a range timer 54. The pulse generator applied pulses at the predetermined pulse repetition frequency (p.r.f.) to the laser 11. The output of the pulse generator 53 is also connected to the 'start' input of a range counter and register 55, which includes a free-running multivibrator connected to a counter and a register for storing the output of the counter. The 'stop' input of the counter is connected to the output of a radio receiver 56. The output of the register 55 is connected together with the output from the range timer 54 to the inputs of a comparator 58, the output of which is connected to the pulse generator. The range timer 54 has also three other outputs, namely an output to the relay 57, an output which is connected to the azimuth and elevation circuits 25 and 26, and a 'stop' output to the control logic 50.

The target simulator shown in FIG. 2 includes a number of, for example, five, infra-red detectors 70 for receiving radiation from the laser 11 connected to a radio transmitter 71. The outputs of the detectors are also applied to an 'under attack' display 72 within the target and through a frequency checking circuit such as a tuning fork relay, to a 'hit' display 74. The detectors 70 are mounted on the exterior of the target so as to receive infra-red radiation from any possible direction of attack.

A frequency checking circuit and a hit display may also be connected to the output of the radio receiver 56 on the weapon to give an indication to the operator of a

hit. Alternatively, or in addition, operation of the hit display 74 on the target may cause a puff of smoke to the emitted and may also disable the target armament.

The control and range-measurement circuits of FIG. 1 and the target simulator of FIG. 2 operate as follows. When the launcher is assumed loaded and the 'Fire' button is pressed by the operator, the control logic 50 generates an output pulse which is applied to the pulse generator 53, to pulse the laser 11, and also to the range timer 54, to start the timer.

Each output pulse from the pulse generator 53 is applied both to the range counter and register 55 to start the counter, and to the laser 11 which generates a pulse of infra-red energy which is directed at the target and received when the laser is correctly aimed, by one of the detectors 70. The output of the detector illuminates the 'under attack' display 72. Also a pulse is applied to the transmitter 71 and is received by the receiver 56 and stops the counter. The time elapsing between the moment of starting and stopping of the counter is proportional to the range of the target, and is stored in the register. The value of the range held in the register is updated whenever a pulse from the laser is received by the detectors 70 and returned via the radio link to the launcher.

The range timer 54 comprises an electronic clock which is started in response to the start pulse from the control logic 50. The output of the clock is a signal proportional to the time since firing the missile, i.e. proportional to the missile range. The missile range is applied by line 41 to the azimuth and elevation circuits 25 and 26 to control the aerodynamic simulation circuits 43. The missile range may also be applied to the diaphragm aperture 16 to decrease the size of the aperture in dependence upon the missile range, to simulate the apparent decrease in size of the missile as it recedes from the launcher.

The range timer 54 also generates after a predetermined time a signal to actuate the relay 57, thus simulating the change from the automatic to the manual phase. The relay 57 controls the position of the switch 34 and also actuates means indicating the change to the operator.

The comparator 58 compares the output of the timer 54 with the range held by the register 55 and, when the missile range substantially equals the target range, generates for a short time a 'hit' signal which is applied to the pulse generator 53. The 'hit' signal changes the p.r.f. of the laser 11, and if the laser is at that instant orientated towards the target, within predetermined limits of accuracy, the 'hit' signal will be detected by the frequency checking circuit 73 and the 'hit' display on the target will be illuminated, indicating that the simulated missile has hit the target.

When the range timer output reaches a predetermined maximum (the time limit), corresponding to the maximum range of the missile being simulated, a stop signal is applied to the control logic 50 to reset the bistable and stop the pulse generator 53.

In order to indicate the nature of the armor on the target, the circuit of FIG. 2 may be modified to generate a double pulse, as described in the aforementioned specification. A single pulse may represent 'soft' target armament and a double pulse 'hard' target armament. The receiver 56 on the weapon then detects

whether a single or a double pulse is received and may inhibit the hit p.r.f. generated by the pulse generator if a double pulse is received.

In order to indicate a near miss, the laser beam may be scanned and the pulse repetition frequency modulated in synchronism with the scanning, as described in the aforementioned specification.

The target range measurement circuits comprising the receiver 56 and counter and register 55 at the weapon location and the transmitter 71 on the target may be omitted if continuously updated target range measurement is not required. The target range may then be fed in manually.

I claim:

1. A missile launcher simulator comprising: aiming means for aiming at a target; a source to provide a beam of electromagnetic radiation directed generally toward the target; a linkage between said aiming means and said source to control the direction of the beam from said source relative to the orientation of said aiming means, said linkage being responsive to a control signal; and means for generating said control signal in response to changes in the orientation of said aiming means and in response to difference information representative of the difference in the orientation of said aiming means and said source; said means for generating including aerodynamic simulation circuit means for introducing a signal component representative of the flight characteristics of a missile.

2. A missile launcher simulator as claimed in claim 1, wherein said source comprises a laser.

3. A simulator as claimed in claim 1, in combination with a target simulator comprising a detector for receiving said beam when said source is orientated with a predetermined accuracy.

4. A simulator as claimed in claim 3, including an indicator connected to the output of said detector for indicating information concerning the accuracy of the aim.

5. A simulator as claimed in claim 3, including means for sending a signal from said target simulator to said launcher simulator when said detector detects said beam.

6. A simulator as claimed in claim 5, wherein said launcher simulator includes a target range timer initiated by the sending of a beam by said source and terminated by the reception of a signal from said target simulator to generate a signal related to the time interval between initiation and termination of said signal indicative of the target range.

7. A simulator as claimed in claim 6, including a missile range timer connected to produce a signal related to the assumed missile range, and means for comparing the outputs of said target range timer and said missile range timer and for generating a hit-enabling signal when said timers are substantially equal.

8. A simulator as claimed in claim 7, wherein said hit-enabling signal is applied to modulate the beam produced by said source.

9. A simulator as claimed in claim 1, including a timer connected to produce a signal indicative of the assumed missile range.

10. A simulator as claimed in claim 1, further comprising means for illuminating a small area within the field of view of said aiming means, the position of said

illuminated area corresponding to the orientation of said source.

11. A simulator as claimed in claim 1, comprising manually-operable means for generating said control signal.

12. A simulator as claimed in claim 11, wherein said manually-operable means comprises at least one potentiometer.

13. A simulator as claimed in claim 1, wherein said difference information is derived from said control signal.

14. A simulator as claimed in claim 1, including a switch connected so as in one position to connect manually-operable means to the input of said generating means and in another position to apply said control signal to the input of said generating means.

15. A simulator as claimed in claim 1, wherein said generating means includes means for forming a signal dependent upon the orientation of said aiming means.

16. A simulator as claimed in claim 15, wherein said forming means comprises a rate gyro and an integrator connected to the output of said gyro.

17. A missile launcher simulator comprising: aiming means for aiming at a target; a source to provide a beam of electromagnetic radiation directed generally toward the target; a linkage between said aiming means and said source to control the direction of the beam from said source relative to the orientation of said aiming means, said linkage being responsive to a control signal; and means for generating said control signal in response to difference information representative of the difference in the orientations of said aiming means and said source, said generating means comprising an aerodynamic simulation circuit including an amplifier, and a kinematic simulation circuit including two integrators connected in cascade.

18. A simulator as claimed in claim 17, wherein the gain of said amplifier is variable in accordance with a signal dependent upon the assumed range of a simulated missile.

19. A missile launcher simulator comprising: aiming means for aiming at a target; means for illuminating a small area within the field of view of said aiming means;

a linkage between said aiming means and said illuminating means for positioning said small area in said field of view in a position dependent upon a control signal; and

means for generating said control signal in response to changes in the orientation of said aiming means and in response to difference information concerning the position of said small area within said field of view, said means for generating including simulation circuit means for introducing a signal component representative of the dynamic characteristics of a missile.

20. A simulator as claimed in claim 19, comprising manually-operable means for generating said control signal.

21. A simulator as claimed in claim 20, wherein said manually-operable means comprises at least one potentiometer.

22. A simulator as claimed in claim 19, wherein said difference information is derived from said control signal.

23. A simulator as claimed in claim 19, including a switch connected so as in one position to connect manually-operable means to the input of said generating means and in another position to apply said control signal to the input of said generating means.

24. A simulator as claimed in claim 19, wherein said generating means includes means for forming a signal dependent upon the orientation of said aiming means.

25. A simulator as claimed in claim 24, wherein said forming means comprises a rate gyro and an integrator connected to the output of said gyro.

26. A missile launcher simulator comprising: aiming means for aiming at a target; means for illuminating a small area within the field of view of said aiming means; a linkage between said aiming means and said illu-

minating means for positioning said small area in said field of view in a position dependent upon a control signal; and means for generating said control signal in response to changes in the orientation of said aiming means and in response to difference information concerning the position of said small area within said field of view; said generating means comprises an aerodynamic simulation circuit including an amplifier, and a kinematic simulation circuit including two integrators connected in cascade.

27. A simulator as claimed in claim 26, wherein the gain of said amplifier is variable in accordance with a signal dependent upon the assumed range of a simulated missile.

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