

[54] **AUTOMATIC MISSILE GUIDANCE SYSTEM**

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[51] **Int. Cl.**.....**F42b 15/04**, F41g 7/02, F41g 7/14

[58] **Field of Search**.....244/3.12, 3.16

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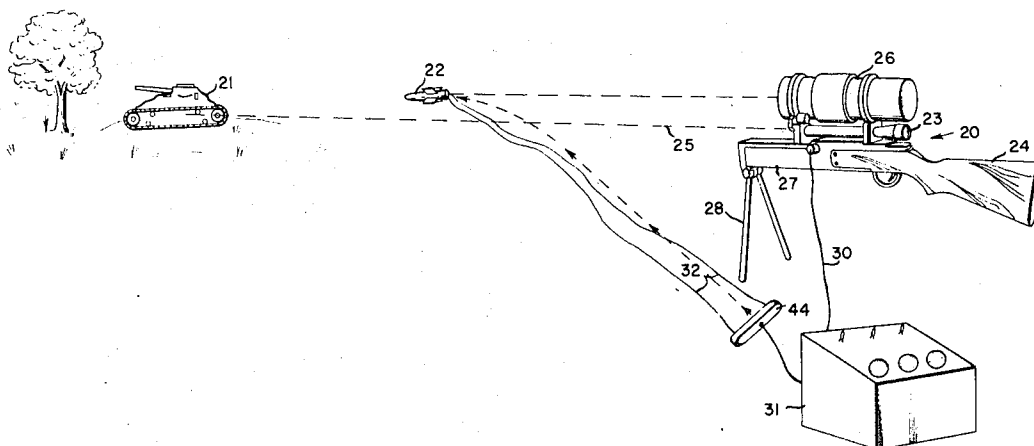
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[57] **ABSTRACT**

The automatic missile guidance system comprises a sight with which a gunner establishes a line-of-sight from the gun position to the target. When the missile is launched, a source of pulsating, radiant energy on the rear of the missile is detected by a guidance unit at the sight. The guidance unit produces steering commands related to the deviation of the missile from the line-of-sight. Means interconnecting the guidance unit and the missile transmits the guidance signals to the missile to direct it along the line-of-sight. This guidance unit to missile connection may be wires which unreel from the missile as it proceeds towards its target.

23 Claims, 12 Drawing Figures



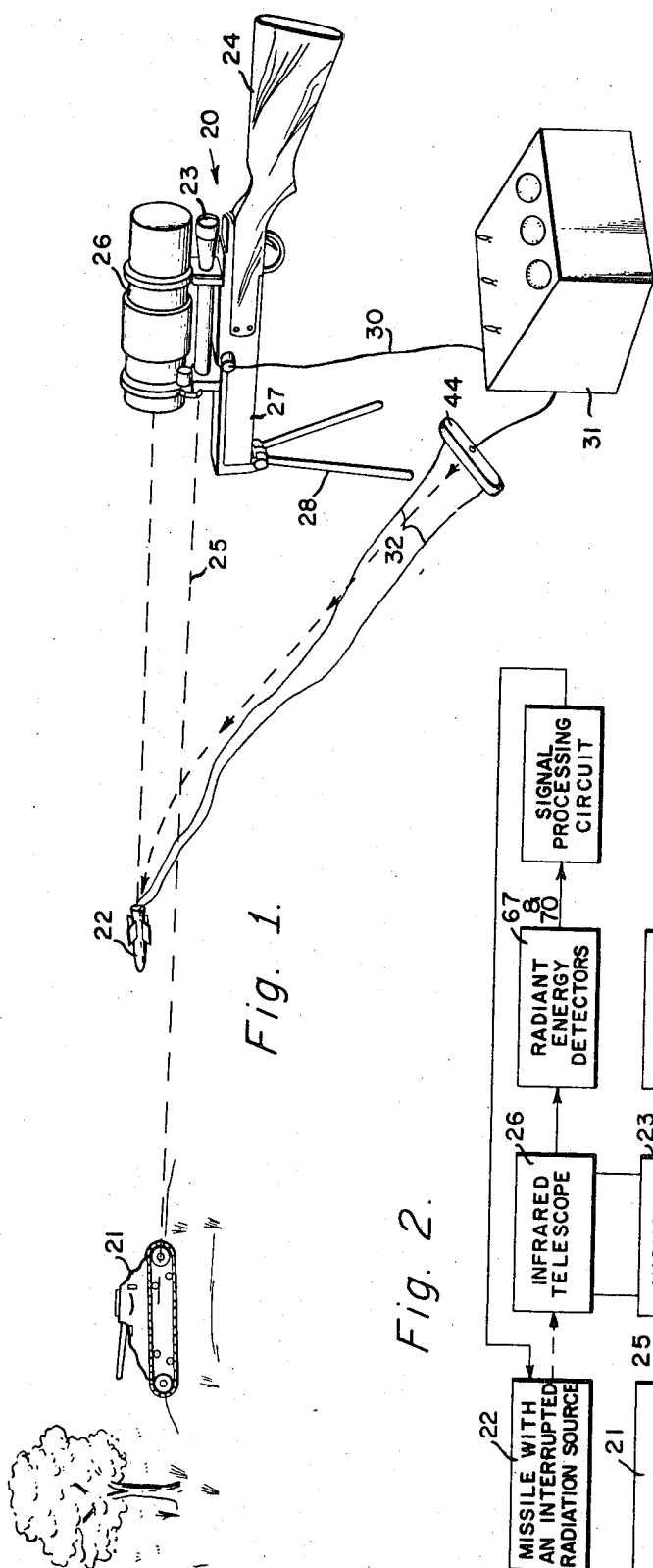


Fig. 1.

Fig. 2.

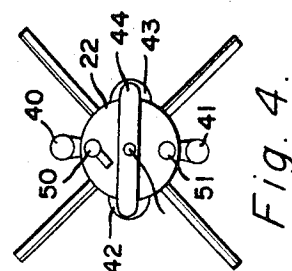
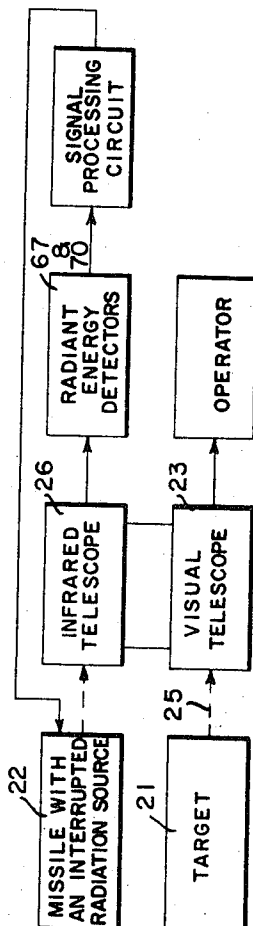


Fig. 4.

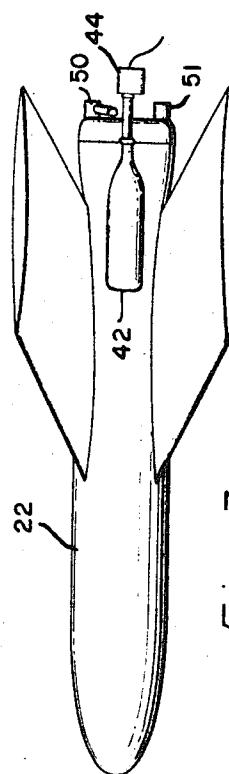


Fig. 3

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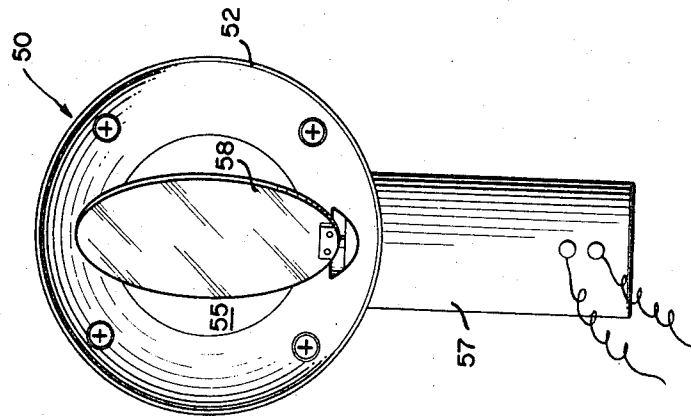


Fig. 6.

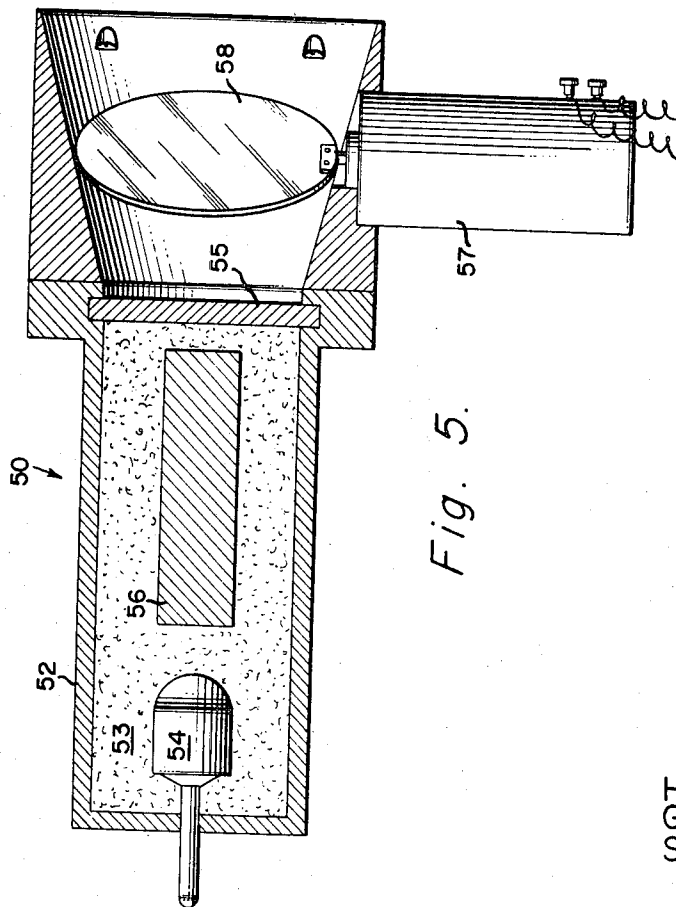


Fig. 5.

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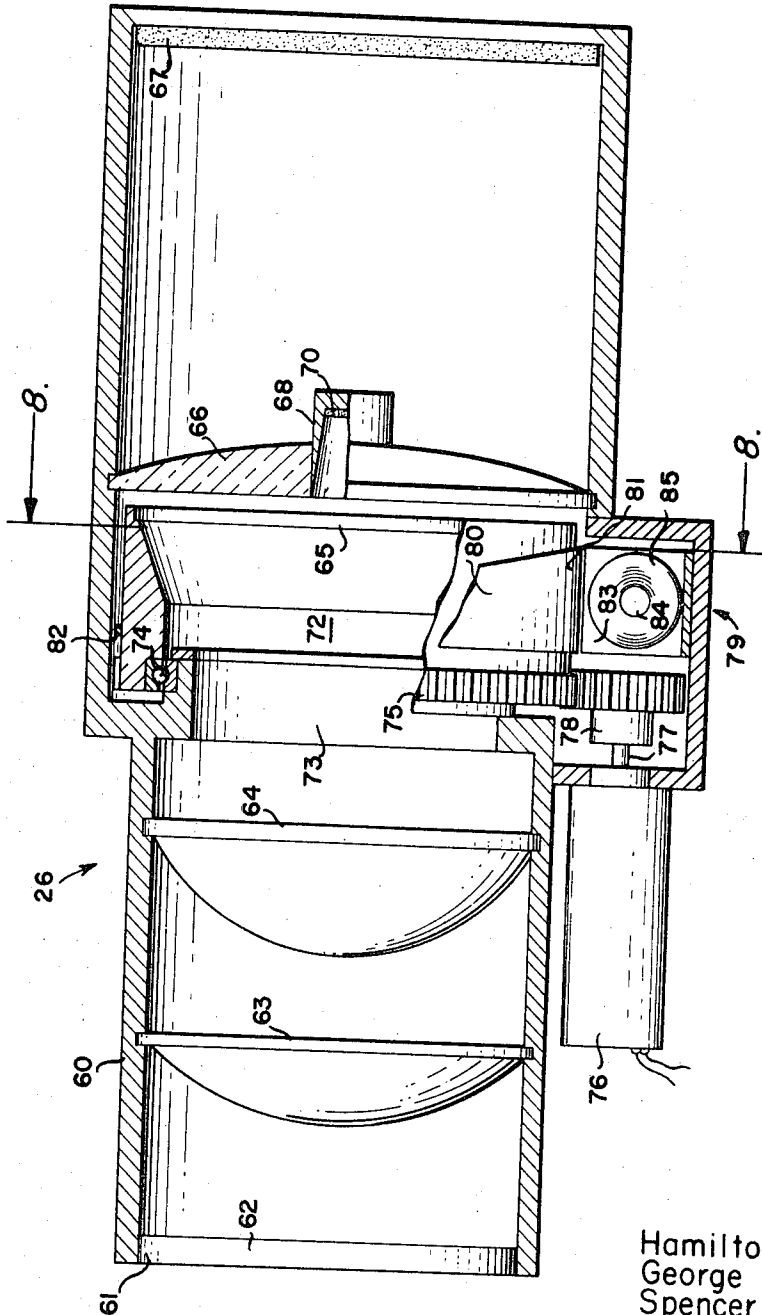


Fig. 7.

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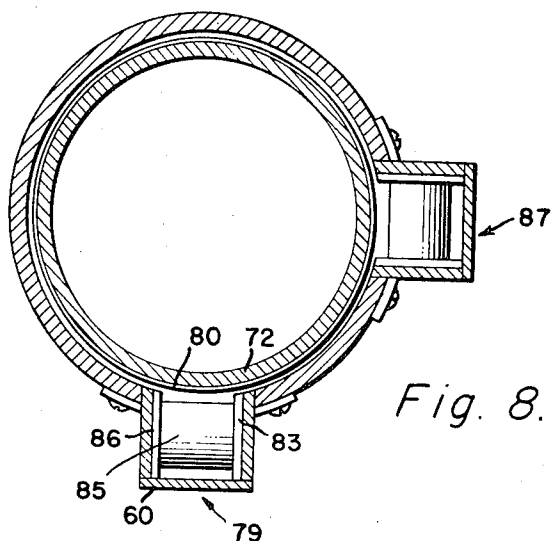


Fig. 8.

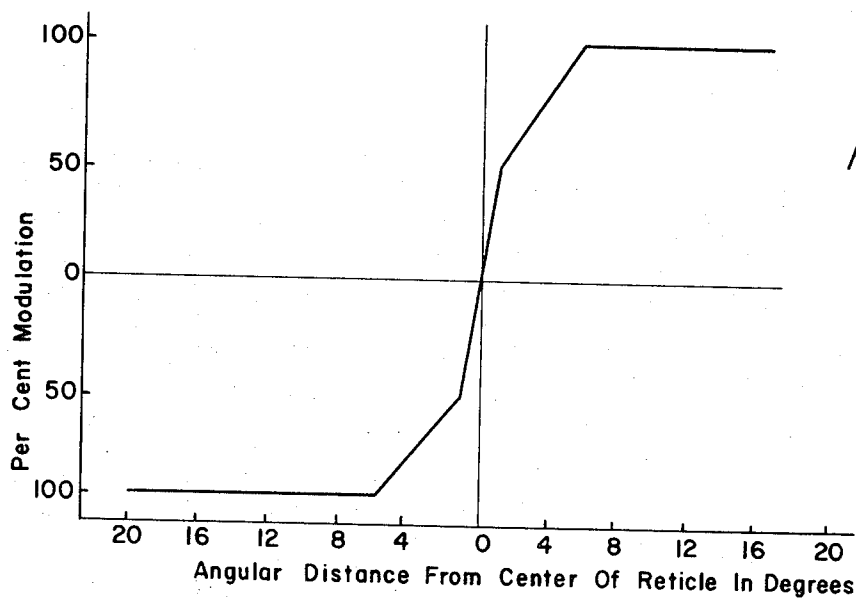


Fig. 10.

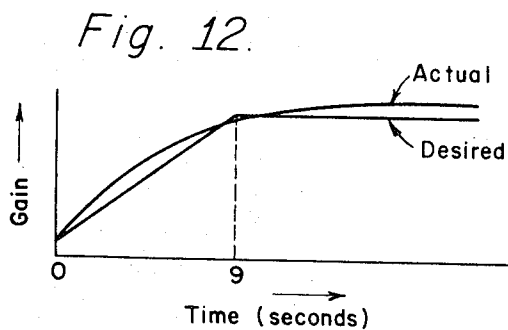


Fig. 12.

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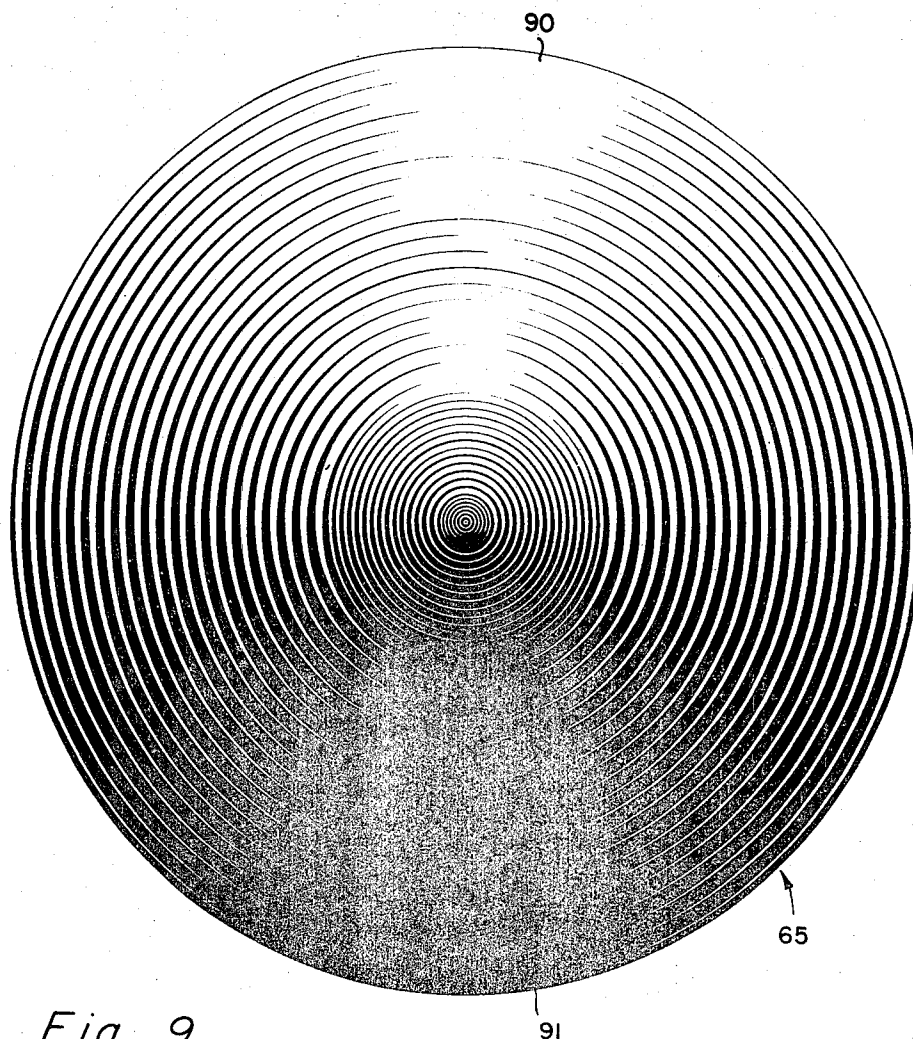


Fig. 9.

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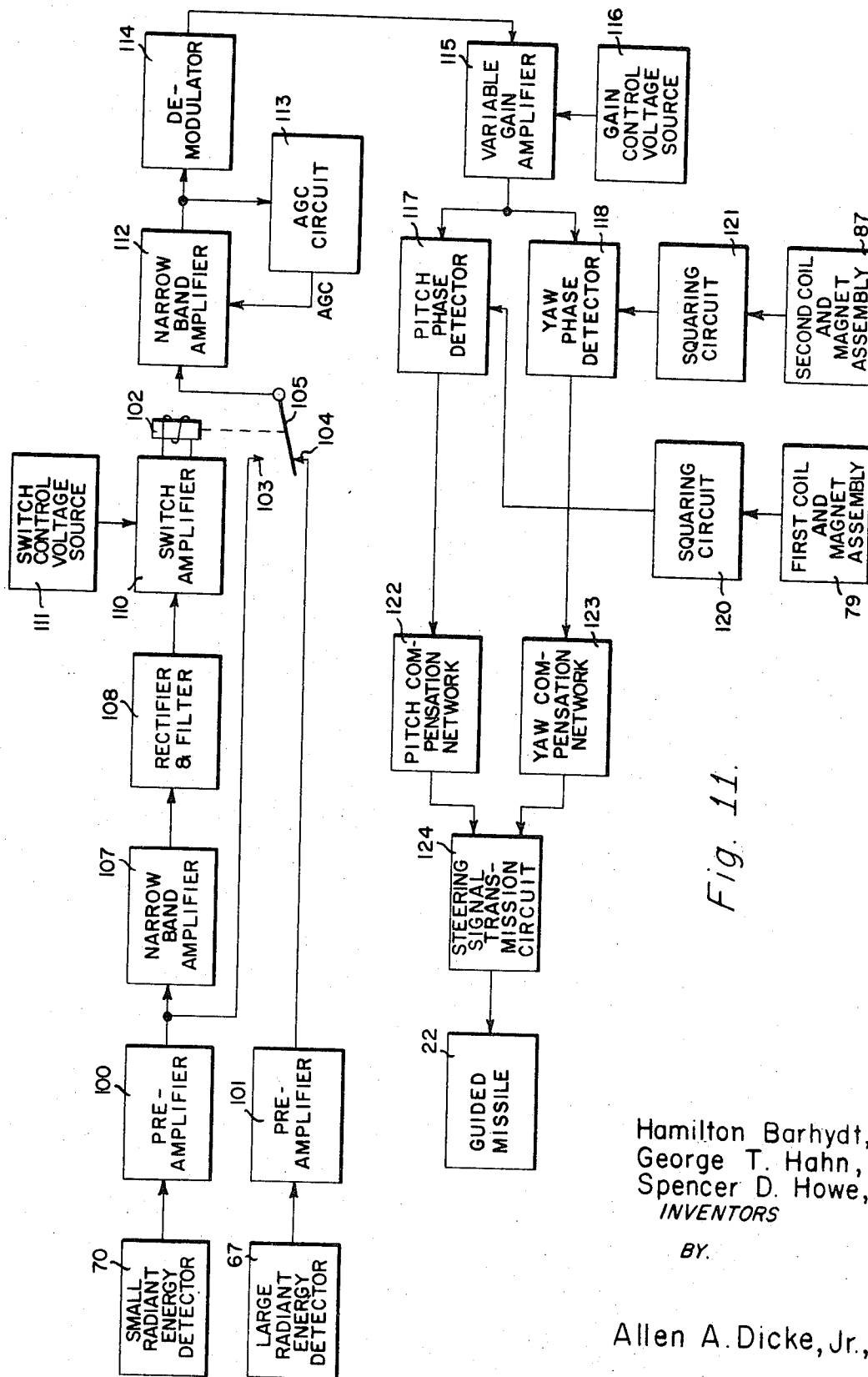


Fig. 11.

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AUTOMATIC MISSILE GUIDANCE SYSTEM

CROSS REFERENCE

This application is a substitute for U.S. Pat. application, Ser. No. 107,861, filed May 4, 1961, for "AUTOMATIC MISSILE GUIDANCE SYSTEM", Hamilton Barhydt, George T. Hahn and Spencer D. Howe, Inventors.

BACKGROUND

The present invention relates to apparatus for remotely controlling the flight of self-propelled rockets and, more particularly, to a guidance system for automatically providing guidance signals to a missile, enabling it to follow a line-of-sight path to a target.

Guidance of small, self-propelled missiles by manual operation of controls that generate guidance signals is difficult, due to the relatively slow reflexes of human operators. An additional disadvantage of manual guidance is the necessity that the operator be highly skilled or highly trained.

In automatic guidance of a missile, it is desirable that the equipment for tracking the target and providing guidance signals remain at the launching point, rather than be incorporated into the missile. By having the tracking and guidance equipment at the launching point, the missile is lighter in weight and, therefore, easier to handle. Furthermore, the missile is less likely to malfunction, because it is less complex and the missile is also less expensive.

When the target tracking and missile guidance equipment is to be portable, it must be small, light and compact. On the other hand, it must operate efficiently, in spite of close proximity to the ground. Radar tracking equipment, for example, is subject to reflection from irregularities in the terrain, usually known as ground clutter. Infrared tracking equipment is subject to unwanted radiation from background and surrounding objects, as well as from the sun, if it is in the field of view.

SUMMARY

The automatic missile guidance system comprises a sight with which a gunner establishes a line-of-sight from the gun position to the target. When the missile is launched, a source of pulsating, radiant energy on the rear of the missile is detected by the sight. A guidance unit connected to the sight produces steering commands related to the deviation of the missile from the line-of-sight. Means interconnecting the guidance unit and the missile transmit the guidance signals to the missile.

Accordingly, it is an object of the present invention to provide an automatic missile guidance system that is small in size, light in weight and relatively inexpensive. Another object of the invention is the provision of a missile guidance system that is automatic in nature and does not require guidance signals to be manually generated by a human operator. Yet another object of the present invention is to provide an automatic missile guidance system that includes missile tracking equipment of a simple, yet effective type. A further object of the invention is the provision of a missile guidance system that includes infrared tracking equipment that is relatively insensitive to background radiation from the sun and other intense sources of radiation.

The following specification and the accompanying drawings respectively describe and illustrate an exemplification of the present invention. Consideration of the specification and the drawings will provide a complete understanding of the invention, including the novel features and objects thereof. Like reference characters are used to designate like parts throughout the figures of the drawing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a pictorial representation of an embodiment of an automatic missile guidance system, in accordance with the present invention;

FIG. 2 is a functional block diagram of the missile guidance system of FIG. 1;

FIG. 3 is a side view of a missile suitable for use in the missile guidance system of FIGS. 1 and 2;

FIG. 4 is a rear view of the missile of FIG. 3;

FIG. 5 is a side view, partly in section, of an embodiment of an interrupted infrared radiation source, in accordance with the invention, for use in the missile guidance system of FIGS. 1 and 2;

FIG. 6 is an end view of the interrupted radiation source of FIG. 5;

FIG. 7 is a side view, partly in section, of an embodiment of an infrared telescope, in accordance with the invention, for use in the missile guidance system of FIGS. 1 and 2;

FIG. 8 is a reduced transverse sectional view of the infrared telescope taken substantially as indicated by line 8-8, FIG. 7, and illustrating the reference signal generators associated with the reticle;

FIG. 9 is an enlarged view of a reticle modulation pattern for use in the infrared telescope of FIG. 7;

FIG. 10 is a graph illustrating the modulation characteristic of the reticle pattern of FIG. 9;

FIG. 11 is a circuit diagram in block form of a signal processing circuit, in accordance with the present invention and used in the missile guidance system of FIGS. 1 and 2; and

FIG. 12 is a graph illustrating the gain characteristic of the variable gain amplifier in the signal processing circuit of FIG. 11.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In accordance with these and other objects of the invention, a guidance unit is provided that may be similar in size and appearance to a rifle. The guidance unit is provided with a visual sight, or telescope, through which an operator views the target, thus establishing a line-of-sight between the launching point and the target. A remotely-controlled missile launched toward the target is viewed by an infrared telescope disposed on the guidance unit and aligned with the visual telescope. The missile is provided with a periodically interrupted infrared source that emits a distinctive frequency, pulsating radiation that is intercepted by the infrared telescope, enabling subsequent circuits to discriminate against background radiation. A rotating reticle is provided in the infrared telescope to amplitude modulate the intercepted pulsating radiant energy to provide information as to the magnitude and direction of deviations of the missile from the line-of-sight. The infrared telescope is provided with dual infrared detection cells to convert the modulated radiant energy into a modu-

lated carrier wave that is supplied to a signal processing circuit. The use of two detection cells permits the infrared telescope to selectively have both a wide field of view and a narrow field of view, the latter having greater sensitivity. The detection cell for the large field of view is not saturated by radiation from intense sources of background energy in its field of view. Provisions are made for automatically switching from the wide field cell to the narrow field cell when the target appears in the narrow field of view, thus providing greater sensitivity and discrimination against sources of extraneous radiation that are not in the narrow field of view. Furthermore, the signal processing circuit has a narrow bandpass characteristic to exclude extraneous signals due to radiation sources other than that on the missile. The signal processing circuit develops steering signals that are transmitted to the missile, causing it to follow the line-of-sight to the target.

An embodiment of an automatic missile guidance system, in accordance with the present invention, is shown pictorially in FIG. 1 and functionally in FIG. 2. A portable guidance unit 20 is provided that may be similar in size and appearance to a rifle stock. The guidance unit 20 is pointed or aimed toward a target 21 and automatically provides steering signals to a ground-launched, self-propelled missile 22 to direct it toward the target 21. The guidance unit 20 includes a visual telescope 23 mounted to a gun stock 24 for use by a human operator to establish a line-of-sight 25 between the guidance unit 20 and the target 21. An infrared telescope 26 is also disposed on the gun stock 24 and aligned with the visual telescope 23 for intercepting pulsating infrared radiation from the missile 22 and detecting deviations of the missile 22 from the line-of-sight 25. Inasmuch as the infrared telescope 26 and the visual telescope 23 are side by side, their optical axes cannot be exactly coincident. However, the few inches difference between the axes make little difference in the operation of the system and the axes may actually intersect at or near the target 21. The forward portion 27 of the guidance unit 20 contains a signal processing circuit that develops steering signals and transmits them to the missile 22 via a cable 30, a box 31 containing missile launching and signal translation circuits, and via wires 32 trailing behind the missile 22.

The gun stock 24 may be of the type normally used for rifles, but modified for the purpose at hand. A folding bipod 28, about which the assembly can pivot, provides a forward support. It will be apparent that other convenient arrangements may be used in place of the gun stock 24. For example, the guidance unit 20 may be mounted to a tripod in a manner such that it may be easily carried and easily pointed in any direction. The visual telescope 23 may have a variable power and may be of the type normally used as a telescopic sight on a rifle, having cross hairs in the center of the field of view.

The missile 22 may be any remotely guided type, such as the Nord Aviation SS-11-A-1, for example, which is described in the Nord Aviation brochure "SS-11 Teleguided Missile Type 5210". This missile 22 receives its guidance signals over wires 32 trailing behind the missile 22. However, the automatic missile guidance system of the present invention is not restricted to use with this particular missile 22, and may

be easily adapted for use with a missile that receives its guidance signals in some other way as, for example, by radio transmission.

Although the missile 22 itself is not part of the present invention, the outside configuration of the missile 22 is shown in FIGS. 3 and 4 to illustrate how the present invention is adapted for use therewith. The missile 22 is initially propelled for a short time by a booster rocket motor which discharges through nozzles 40 and 41 disposed on opposite sides of the missile 22 near the aft end thereof, and is subsequently propelled for the remainder of the flight by a sustainer rocket motor. The sustainer motor nozzle is not shown in FIGS. 3 and 4, but is centrally located in the aft end of the missile 22. Control moments result from solenoid-actuated spoilers operating in the exit area of the sustainer nozzle. The spoilers oscillate continuously and, by controlling the spoiler duty cycle, proportional control is achieved. Guidance signals are received by the missile 22 through the wires 32 connected to the box 31, which may be representative of the Nord T-9 generator, for example, and which contains missile firing circuits and circuits for converting guidance signals into the form best adapted for transmission to the missile 22. The box 31 may also contain manual guidance arrangements. On the missile 22, the wires 32 are initially contained in two bobbins disposed in bobbin cases 42 and 43 disposed on opposite sides of the missile 22 near the aft end thereof. The wires 32 are unreel during flight of the missile 22. Since the missile 22 is intentionally rolled during flight, the guidance signals are resolved into pitch and yaw commands by a vertical gyro and a four-segment commutator. The near ends of the guidance wires 32 are attached to an anchor block 44 initially attached to the rear of the missile 22, as seen in FIGS. 3 and 4, but left behind as the missile 22 is launched, as shown in FIG. 1.

In accordance with the present invention, the missile 22 is provided with an interrupted radiation source 50, disposed on the aft end thereof, that generates distinctive infrared radiation pulsating at a constant frequency. As will be fully described hereinafter, pulsation is caused by an interrupter operated by a battery 51, also located on the aft end of the missile 22. The battery 51 is connected to the source 50 when the missile 22 separates from the block 44. The interrupted infrared radiation source 50 is shown in FIGS. 5 and 6 and comprises a cylindrical housing 52 filled with a pyrotechnic composition 53 that produces a thermite reaction when ignited. A suitable mixture for the pyrotechnic composition 53 may be, for example, iron oxide, 56 percent (by weight); aluminum powder, 14 percent; boron, 3 percent; and barium chromate, 27 percent. Another suitable mixture is molybdenum trioxide, 80 percent and aluminum powder, 20 percent. Other mixtures may also be found to be satisfactory. An electrically operated firing squib 54 is disposed inside the case 52 in contact with pyrotechnic composition 53. The radiating surface is a molybdenum disk 55, having a zirconium carbide coating and which is disposed near one end of the housing 52. At least one heavy metal bar 56 is embedded in the pyrotechnic composition 53 to produce a hot metal mass that heats the molybdenum disk 55 when the radiation source 50 is ignited. The bar 56 may be made of iron or may be made of 90 percent tungsten and 10 percent copper or nickel, for example.

The radiant energy from the molybdenum disk 55 is interrupted by a rotating disk 58, similar to a butterfly valve, and rotatably secured adjacent the molybdenum disk 55. The butterfly disk 58 is mechanically coupled at the circumference thereof to the shaft of a direct current motor 57, having a regulated speed which, in the present example, is 100 revolutions per second. The motor 57 is secured to the housing 52 of the radiation source 50. As the butterfly disk 58 rotates, it interrupts the radiation from the molybdenum disk 55 twice each revolution to produce interrupted infrared radiation pulsating at a frequency of 200 cycles per second.

It will be understood that other types of sources of interrupted radiation may be utilized, if desired. For example, an intense electric lamp, having an interrupter, produces pulsating radiation suitable for use in a system, according to the present invention. Additionally, mechanical devices may be employed to cause pulsation of the plume of exhaust gases from the rocket motor or a portion of these gases that is bypassed to a separate outlet.

The infrared telescope 26, shown in FIG. 7, has a generally cylindrical outer case 60, with an entrance aperture 61 at one end to admit radiant energy. A window 62 is disposed in the entrance aperture 61 and may, if desired, have a multilayer interference filter deposited on the inner surface to pass only radiation having wavelengths within a desired band. Adjacent the window 62 are first and second objective lenses 63 and 64 that focus intercepted radiant energy onto a flat surface of a disk-shaped reticle 65 disposed transversely to and concentric with the optical axis of the objective lenses 63 and 64.

Adjacent to the reticle 65 is a condensing lens 66. A large radiant energy detector 67 is disposed adjacent and generally parallel thereto in the end of the infrared telescope case 60, opposite the entrance aperture 61. The condensing lens 66, in effect, focuses the image of the entrance aperture 61, as seen through the first and second objective lenses 63 and 64 and the reticle 65, onto the large radiant energy detector 67, and, thus, the radiant energy passing through the condensing lens 66 more or less uniformly illuminates the large radiant energy detector 67. A large radiant energy detector is required so that radiant energy from the sun or other intense sources of background radiation, which may lie within the large field of view of the infrared telescope 26 will not saturate the signal generating capability of the detector and is also required by a law of geometrical optics, known as the Abbe sine condition, which states, in effect, that for any given field of view, there is a minimum size, increasing with the size of the field of view, for the image of the entrance aperture 61 that can be focused by the condensing lens 66 onto a detector. Both these conditions are met, in the present example, by the large radiant energy detector 67, which is approximately 3 inches on a side. A detection cell of this size is normally a cell blank from which smaller cells are ordinarily cut, or several cell blanks placed side by side.

In the center of the condensing lens 66, concentric with the optical axis of the lenses 63, 64 and 66, is located a generally cylindrical light pipe 68, having a small radiant energy detector 70 disposed at the end thereof. The internal shape of the light pipe 68 is that of a hollow, truncated cone, the larger diameter end being

flush with the surface of the condensing lens 66 adjacent the reticle 65. The smaller internal diameter end of the light pipe 68 extends away from the reticle 65 and through the opposite surface of the condensing lens 66. The internal surface of the light pipe 68 is highly polished and the small radiant energy detector 70 is disposed at the small diameter end of the light pipe 68. Energy intercepted by the light pipe 68 is directed to the small detector 70 by reflection from the inner surface of the light pipe 68. Thus, the light pipe 68 acts as a condensing lens to concentrate diverging energy passing through the reticle 65 onto the small detector 70.

The optical elements of the infrared telescope 26 may be made of any material that is transparent to the radiant energy of interest and has a suitable index of refraction. For intercepted radiant energy in the infrared spectrum, silicon or sapphire, for example, may be used. Lenses for use in the infrared spectrum may be opaque to visible light. The radiant energy detectors 67 and 70 may be made of any suitable material for converting radiant energy in the spectrum of interest into an electrical signal. In the present embodiment of the invention, lead sulfide, for example, will be found satisfactory. Although the present invention is described with reference to operation with radiant energy in the infrared portion of the radiant energy spectrum, it is to be expressly understood that the apparatus may be easily adapted for use with radiant energy in other parts of the radiant energy spectrum, such as in the visible or ultraviolet portion, for example. This may be done by proper selection of the lens materials and of the radiant energy detectors 67 and 70, in accordance with well-known principles.

The field of view of the infrared telescope 26 is 40 degrees. Images of sources of radiant energy formed on the reticle 65 by the objective lenses 63 and 64 are small and sharply defined in the central portion of the reticle 65. However, sources near the outer edge of the field of view form images near the circumference of the reticle 65 that are slightly out of focus and, consequently, larger and somewhat blurred. Inasmuch as accuracy is required only on or near the optical axis of the infrared telescope 26, the blurring of images distant from the optical axis is not deleterious to the operation of the system.

It will be apparent that the major portion of the optical field of view of the infrared telescope 26 is intercepted by the large radiant energy detector 67. However, the small radiant energy detector 70 intercepts the central 6 degrees of the optical field of view. Thus, the infrared telescope 26 has dual concentric radiant energy detectors 67 and 70, one providing a wide field of view and the other providing a narrow field of view.

The reticle 65 amplitude modulates intercepted radiant energy in a manner that will be fully described hereinafter. The reticle 65 is a flat disk made of a material that is transparent to radiation in the spectrum of interest, but has a partially opaque modulating pattern superimposed thereon. The reticle 65 is rotated to produce the modulation, and for this purpose, is mounted at its circumference in a generally cylindrical holder 72. An internal projection 73 of the infrared telescope case 60 rotatably supports the reticle holder 72 by means of ball bearings 74 that engage the inner

surface of the holder 72. A ring gear 75 is disposed on the outside of the reticle holder 72. An electric motor 76 disposed outside the infrared telescope case 60 has a shaft 77 projecting into the case 60, to which is attached a driving gear 78 that is meshed with the ring gear 75. In this manner, the motor 76 causes the reticle 65 to rotate about its center, which is on the optical axis of the objective lenses 63 and 64. The reticle 65 is rotated at a constant rate of 18 revolutions per second in the present example.

The reticle 65 has associated with it an arrangement for producing phase reference signals indicative of the instantaneous angular position of the reticle 65. For this purpose, the reticle holder 72 is provided with a band 80 around the outside thereof, adjacent the ring gear 75. The band 80 is made of magnetic material, such as steel, while the reticle holder 72 is made of non-magnetic material, such as aluminum. The band 80 tapers in width from a maximum width point 81 (FIG. 7), to a minimum width point 82. The band 80 tapers linearly and the maximum point 81 is diametrically opposite the minimum point 82. A first coil and magnet assembly 79 is provided, with a first pole piece 83 fastened to the outer case 60 of the infrared telescope 26 adjacent and extending toward the reticle holder 72 and spaced slightly away from the band 80. A permanent bar magnet 84 extends out from the pole piece 83 and has wound around it a wire coil 85. Referring to FIG. 8, a second pole piece 86 is at the other side of the magnet 84 and also extends toward the band 80. The faces of the pole pieces 83 and 86 are as broad as the width of the band 80 at the maximum point 81. The case 60 that encloses the phase reference signal coil and magnet assembly 79 is nonmagnetic.

Thus, the magnet 84 has a magnetic circuit that extends from one pole of the magnet 84 through the associated pole piece 83, through a portion of the band 80 on the reticle holder 72, through the second pole piece 86 to the remaining pole of the magnet 84. As the reticle holder 72 rotates, the width of the band 80 in the magnetic circuit of the magnet 84 varies, so that a variable reluctance path exists between the poles of the magnet 84. This, in turn, causes a potential to be developed in the coil 85 around the magnet 84. Hence, as the reticle holder 72 and reticle 65 rotate, a periodic signal is generated in the coil 85, whose phase is directly related to the instantaneous angular position of the reticle holder 72. A second coil and magnet assembly 87 (FIG. 8), similar to the first, is located in a position 90° displaced from the first coil and magnet assembly 79 and produces a second phase reference signal that is displaced 90 degrees in phase from the first phase reference signal.

The modulation pattern superimposed on reticle 65, and shown in FIG. 9, is opaque to radiation in the spectrum of interest. The pattern can be considered to consist of a series of adjacent, concentric, circular bands. Each band is divided into two parts, one part of which is opaque and the other part remaining transparent, by a circle that is not concentric with the center of the pattern. The area in each band between the outer boundary circle and the dividing circle is opaque, and the area between the dividing circle and the inner boundary circle is transparent. In the outer part of the reticle 65, the dividing circle in each band is tangent with the outer

boundary circle in a maximum transmission zone 90 and tangent with the inner boundary circle in a minimum transmission zone 91, 180° away from the maximum. In the inner portion of the reticle 65, the dividing circle is not tangent to either the inner or outer boundary circles, but the separation between the dividing circle and the outer boundary circle in the maximum transmission zone 90 is equal to the separation between the dividing circle and the inner boundary circle in the minimum transmission zone 91. Furthermore, in the inner portion of the reticle 65, the circular bands themselves are narrower than in the outer portion.

Thus, the pattern comprises concentric, circular, opaque lines that progressively increase in width around the reticle 65 from a minimum width in the maximum transmission zone 90 to a maximum width in the minimum transmission zone 91 and decrease again to the minimum width. The size of the image focused on the reticle 65 is larger than the width of the circular bands. The bands near the center of the reticle 65 are narrower than the outer bands, since the image size is smaller near the center. Since the image is larger than the bands, the radiant energy transmitted by the reticle 65 is amplitude modulated in a sinusoidal fashion as the reticle 65 is rotated.

The reticle pattern is not uniform over the entire surface of the reticle 65, as may be seen in FIG. 9, but is divided into three distinct concentric regions having slightly different modulation characteristics. The central portion of the field of view of the infrared telescope 26, extending from the optical axis to a circle 1° away therefrom, falls on a region of the reticle 65 where the pattern comprises closely spaced opaque lines that provide a modulation percentage varying from zero percent modulation at the center to 50 percent modulation at the circumference thereof. That is, radiant energy producing an image at the center of the reticle 65 passes through the reticle 65 unmodulated, and radiant energy producing an image 1° away from the center of the reticle 65 is only 50 percent intercepted or modulated by the opaque pattern in the minimum transmission zone 91. The portion of the optical field of view that extends between 1° and 6° from the optical axis falls on a second region of the reticle in which the opaque lines are not quite as closely spaced as in the first or central region, and in which the percent modulation varies from 50 percent to 100 percent as the angular distance from the center of the pattern increases. The third or outer region has opaque lines spaced farther apart than the other two regions, and in which the modulation is 100 percent throughout. The modulation characteristic of the reticle is illustrated graphically in FIG. 10, where percent modulation is plotted along the ordinate, as a function of the angular distance from the center of the reticle in degrees along the abscissa.

It will be apparent from the graph of FIG. 10 that the percentage of modulation of radiant energy from the radiation source 50 on the guided missile 22 is a function of the angular distance from the optical axis of the image thereof. Accordingly, the amplitude of the modulation is indicative of the angular deviation of the missile 22 from the line-of-sight 25. Furthermore, the closer the image is to the optical axis of the infrared telescope 26, the greater is the amount of modulation

produced per unit of angular deviation. This is indicated by the steep slope of the curve of FIG. 10, as it passes through zero. Accordingly, the subsequent control circuits do not need to have an extremely high gain and the noise in the system is maintained at acceptable levels, due to a relatively large deviation signal being provided, even when the deviation is small.

The opaque pattern may be applied to the reticle 65 by various methods. One process that has been found satisfactory is a photographic process in which the surface of the reticle 65 to which the pattern is to be applied is first silvered and then coated with a photo-resist material. An image of the pattern is focused on the surface of the reticle 65, after which the reticle 65 is placed in an etchant bath, where portions of the silvered area are etched away to leave the opaque pattern.

FIG. 11 shows a circuit diagram in block form of an embodiment of a signal-processing circuit, in accordance with the present invention. In this circuit, the radiant energy from the source 50 on the missile 22 intercepted by the infrared telescope 26 is converted into guidance signals that are transmitted to the missile 22. As mentioned previously, the interrupted radiation source 50 on the missile 22 emits radiant energy pulsating at 200 cycles per second. Pulsating radiant energy intercepted by the infrared telescope 26 is amplitude modulated by the reticle 65 at 18 cycles per second and falls on the radiant energy detectors 67 and 70. The modulated, pulsating radiant energy is converted to an amplitude-modulated electrical carrier wave, or tracking signal, by the detectors 67 and 70. The carrier wave frequency is 200 cycles per second and the modulating wave frequency is 18 cycles per second, so that the tracking signal occupies a frequency band from 182-218 cycles per second.

Electrical signals from the small radiant energy detector 70 are applied to a preamplifier 100 for amplification. The preamplifier 100 may be any low noise amplifier circuit having a bandwidth of approximately 150-300 cycles per second. Electrical signals from the large radiant energy detector 67 are also applied to the input of a preamplifier 101, which may be identical to the preamplifier 100 associated with the small detector 70. Output signals from the preamplifiers 100, 101 are applied to a single-pole, double-throw relay 102, the small cell preamplifier 100 being connected to the normally open contact 103 and the large cell preamplifier 101 being connected to the normally closed contact 104. Thus, either the signal from the small detector 70 or the signal from the large detector 67 appears at the switch arm 105, depending upon whether the switching relay 102 is energized or de-energized. The preamplifiers 100, 101 are phase compensated to provide identical amounts of phase shift to signals amplified thereby. Accordingly, when the relay 102 switches between the outputs of the preamplifiers 100, 101, there will be no phase discontinuity in the tracking signal.

A circuit is provided for automatically controlling the switching of the relay 102. The output of the small cell preamplifier 100 is connected to the input of a narrowband amplifier 107. The bandwidth of this amplifier 107 is from approximately 175 to 225 cycles per second, so that it is responsive only to the tracking

signal derived from the radiation from the missile 22. Inasmuch as background radiation is not pulsating at 200 cycles per second, the electrical signal resulting therefrom is discriminated against by the narrowband amplifier 107, because its frequency is outside the pass-band thereof. The output signal of the narrowband amplifier 107 is applied to a rectifier and filter 108 that develops a direct-current voltage which is applied to the input of a switch amplifier 110. The relay 102 has its energizing coil connected to the output of the switch amplifier 110.

The relay 102 is normally not energized and, in this condition, the switch arm 105 is connected to the large detector 67. When a signal of sufficient amplitude and having a frequency in the band from 175 to 225 cycles per second appears at the output of the small detector 70, it is amplified, rectified and applied to the switch amplifier 110, which energizes the relay 102. Subsequently, if the signal from the small detector 70 falls below a predetermined amplitude, the relay 102 is de-energized. Thus, when the missile 22 is in the narrow 6° field of view of the small detector 70, the relay 102 automatically switches to the small detector 70, and switches back again when the missile 22 leaves the field of view of the small detector 70.

To prevent rapid switching back and forth of the relay 102 when the missile 22 momentarily passes through the field of view of the small detector 70, the rectifier and filter 108 is provided with a suitable time constant. Thus, the missile 22 must be in the field of view of the small detector 70 for a predetermined length of time before the voltage at the output of the rectifier and filter 108 can increase to the level at which switching takes place. Similarly, when the missile 22 leaves the field of view of the small detector 70, the voltage at the output of the rectifier and filter 108 gradually decreases to the switching level. The switch amplifier 110 is biased to have a suitable threshold level, so that when the applied voltage is above the threshold, the relay 102 is energized and, when the applied voltage is below the threshold, the relay 102 is de-energized.

When the missile 22 is close to the target 21, the relay 102 is locked into the energized position. This is accomplished by means of a switch control voltage source 111 that applies a voltage that exceeds the threshold level to the input of the switch amplifier 110 at the end of a predetermined time interval. The switch control voltage source 111 is a capacitor-charging circuit that begins operation at the time the missile 22 is fired. After 6.7 seconds, the potential at the output of the switch control voltage source 111 exceeds the threshold level, causing the relay 102 to be locked into the energized position.

The switch arm 105 of the relay 102 is connected to the input circuit of a second narrowband amplifier 112 that is similar to the narrowband amplifier 107 in the relay control circuit. Specifically, the narrowband amplifier 112 has a bandwidth of 175 to 225 cycles per second to pass only the tracking signal while excluding background signals. An AGC (Automatic Gain Control) circuit 113 is connected to the narrowband amplifier 112. This circuit 113 rectifies and filters the tracking signal appearing at the output of the narrowband amplifier 112 to develop an AGC voltage that is

applied to the narrowband amplifier 112 to control the gain thereof. Thus, as long as the missile 22 is in the field of view of the infrared telescope 26, the tracking signal appearing at the output of the narrowband amplifier 112 has a substantially constant amplitude.

A demodulator 114 is also connected to the output of the narrowband amplifier 112 and comprises a rectifier and filter that demodulates the tracking signal to recover the 18-cycle-per-second modulating wave or error signal introduced by the reticle 65. The error signal is applied to the input circuit of a variable gain amplifier 115 that increases the amplitude of the missile error signal as the missile 22 approaches the target 21 to account for the increasing distance between the guidance unit 20 and the missile 22. If this were not done, the missile 22 would undercorrect for errors as it approached the target 21. Accordingly, the gain of the variable gain amplifier 115 is gradually increased throughout the time of flight, in accordance with the graphical representation shown in FIG. 12, in which the gain of the amplifier 115 is plotted along the ordinate as a function of elapsed missile flight time plotted along the abscissa.

The variable gain amplifier 115 is an amplifier having a negative feedback loop, including a resistive voltage divider network. A pair of diodes connect a relatively low resistance in shunt with a portion of the feedback network. The diodes are normally biased to be nonconductive, at which time the negative feedback is large and the gain of the amplifier 115 is low. When the diodes become conductive, the impedance of the feedback network is decreased, which decreases the negative feedback and the gain of the amplifier 115 increases. The gain of the variable gain amplifier 115 is controlled by a gain control voltage source 116, which is similar to the switch control voltage source 111 of the signal switching circuit. The gain control voltage source 116 includes a capacitor charging circuit that is set into operation when the missile 22 is fired. The exponential charging voltage is applied to the diodes in the feedback network of the variable gain amplifier 115 to cause them to gradually become more and more conductive as the charging voltage increases.

The error voltage from the output of the variable gain amplifier 115 is applied to a pair of circuits that develop steering signals. These circuits are a pitch phase detector 117 and a yaw phase detector 118, which may be conventional phase detector circuits. Reference signals for the pitch and yaw phase detectors 117 and 118 are derived from the coil and magnet assemblies 79 and 87 associated with the reticle holder 72, previously described. These coil and magnet assemblies 79 and 87 develop periodic wave reference signals that are 90° displaced in phase with respect to each other, and have a fixed phase relationship to the angular position of the reticle holder 72. The pitch and yaw reference signals are applied to squaring circuits 120 and 121 that amplify and clip the reference signals to develop square waves that are then applied to the pitch and yaw phase detectors 117 and 118.

To establish the proper phase relationship between the modulation pattern on the reticle 65 and the pitch and yaw reference signals, an image of the radiation source 50 is focused on the reticle 65 at a position vertically displaced from the center of the reticle 65. The

angular position of the reticle 65, with respect to the reticle holder 72, is manually adjusted until the yaw phase detector 118 provides no steering signal output and the pitch phase detector 117 provides a maximum steering signal output when the guidance unit 20 is operating. When the image is moved to a position laterally displaced from the center of the reticle 65, the pitch phase detector 117 provides no steering signal output and the yaw phase detector 118 provides a maximum steering signal output.

The output circuits of the pitch and yaw phase detectors 117, 118 are each connected to corresponding pitch and yaw compensation networks 122, 123 that provide stability and damping, in accordance with well-known principles of feedback control systems. That is, the compensation networks 122 and 123 modify the natural response of the guidance system to disturbances thereof by means of such well-known techniques as basic lead compensation and error rate damping, for example. The compensation networks 122, 123 are specifically adapted to the type of missile 22 with which the guidance system is to be used. This compensation provides guidance system stability and satisfactory transient response, regardless of displacements of the missile 22 from the line-of-sight 25 at launch and internal system noise, for example. In addition, a gravity bias may be provided to prevent collision of the missile 22 with the ground during overshoots around the line-of-sight 25.

The output of the pitch and yaw compensation networks 122, 123 are connected to a steering signal transmission circuit 124 which applies the steering signal to the missile 22. The steering signal transmission circuit is, in the present example, a box 31, shown in FIG. 1, which is representative of the Nord T-9 generator and which contains firing and signal conversion circuits and to which are connected the wires 32 trailing behind the missile. It will be understood that the steering signal transmission circuit 124 may be any other form of guidance command link, such as a radio circuit.

In operation, the portable guidance unit 20 is aimed toward the target 21 by the operator who sights through the visual telescope 23. The operator maintains the portable guidance unit 20 trained on the target 21 at all times during the flight of the missile 22, even if the target 21 is moving. This establishes a line-of-sight 25 between the guidance unit 20 and the target 21. The missile 22 is then launched into the field of view of the infrared telescope 26. The launching process sets into operation the interrupted radiation source 50 on the rear of the missile 22, which emits infrared energy pulsating at 200 cycles per second. The launching of the missile 22 also sets into operation the charging of capacitors in the switch control voltage source 111 and the gain control voltage source 116.

The pulsating radiant energy from the missile 22 is intercepted by the infrared telescope 26 where it is focused on the reticle 65. The reticle 65 modulates the intercepted radiant energy at 18 cycles per second, the phase of the modulating signal being dependent upon the angular direction of the missile 22 from the line-of-sight 25. The amplitude of the modulating signal is dependent upon the radial distance of the missile 22 from the line-of-sight 25. The modulated intercepted radiant energy is then concentrated on the radiant energy de-

tectors 67 and 70, which convert the radiant energy into an amplitude-modulated electrical carrier wave.

It will be apparent that background radiation from objects other than the missile 22 and including the sun, do not result in a similar electrical signal because the radiant energy emitted by background objects is not pulsating at 200 cycles per second. However, background radiation will be modulated to some extent at 18 cycles per second by the reticle 65. Signals from the radiant energy detectors 67 and 70 are applied to the preamplifiers 100, 101, which have a bandwidth of 150 to 300 cycles per second and, therefore, will not pass electrical signals at 18 cycles per second that are derived from background radiation.

Even when intense sources of background radiation, such as the sun, are in the field of view, the large detector 67 is not saturated. Thus, the pulsating energy from the missile 22 continues to produce electrical signals at the output of the large detector 67. Accordingly, the missile signal is at all times distinguishable from background signals.

The amplitude modulated electrical carrier wave, or tracking signal, then passes through the contacts of the relay 102 to the input of the narrowband amplifier 112, which further discriminates against extraneous signals. The AGC circuit 113, associated with the narrowband amplifier 112, maintains the tracking signal at a substantially constant amplitude at the output of the narrow band amplifier 112. However, it will be understood that the time constant is sufficiently long so that the modulation will not be suppressed by gain control action. The tracking signal is then applied to the demodulator 114, where it is demodulated to recover the 18-cycle-per-second modulating wave or error signal introduced by the reticle 65. The phase of the error signal is a function of the angular direction of the image from the center of the reticle 65 and the amplitude of the error signal is a function of the radial distance of the image from the center of the reticle 65.

The error signal is applied to the input of the variable gain amplifier 115, which adjusts the amplitude of the error signal to account for the increasing distance of the missile 22 from the guidance unit. The error signal is then applied to the pitch and yaw phase detectors 117 and 118, which convert the error signal from polar form into rectangular form by means of the phase reference signals developed by the coil and magnet assemblies 79 and 87 associated with the reticle 65. This operation results in a pitch steering signal at the output of the yaw phase detector 118. The pitch and yaw steering signals are then applied to the pitch and yaw compensation networks 122 and 123, which provide guidance system stability. The steering signals are then applied to the steering signal transmission circuit 124, where they are transmitted to the missile 22 to correct for deviations thereof from the line-of-sight 25.

Inasmuch as this is a closed loop system, the missile 22 always tends to follow the line-of-sight 25. If the missile 22 is not on the line-of-sight 25 at launch, the error signal produced steers the missile 22 back onto the line-of-sight 25 because the system operates to reduce the error signal and the steering signals to zero.

Initially, the missile 22 may have a large heading error, with respect to the line-of-sight 25. However, the extremely wide field of view of the infrared telescope

26 intercepts the pulsating radiation from the missile 22 and initiates the controlling signals to bring it back to the line-of-sight 25. As the missile approaches the line-of-sight 25, it enters the central 6° of the field of view of the infrared telescope 26, at which time the pulsating infrared radiation falls on the small radiant energy detector 70. The result is that the tracking signal is applied to the narrow-band amplifier 107 in the signal switching circuit, which discriminates against background signals and applies it to a rectifier and filter 108 that, after a short time interval, builds up a voltage that exceeds the threshold of the switch amplifier 110, causing the relay 102 to connect the output of the small detector 70 into the guidance system.

The narrow field of view of the small detector 70 eliminates many sources of background radiation and, therefore, provides increased discrimination against background signals. The small detector 70 also provides greater sensitivity. Should the missile 22 leave the central 6° of the field of view of the infrared telescope 26, the voltage at the output of the rectifier and filter 108 decreases after a short time interval to a value less than the threshold level of the switch amplifier 110, at which time the large detector 67 is connected into the guidance loop by the relay 102. 6.7 seconds from the time of missile launch, the gradually increasing voltage from the switch control voltage source 111 exceeds the threshold of the switch amplifier 110 and locks the small detector 70 into the guidance loop as, at that time, the missile 22 should be within the central 6° of the field of view of the infrared telescope 26.

When the image is on the central 1 degree of the reticle 65, the error signal is larger per unit of angular deviation from the center of the reticle 65. Thus, the signal processing circuit does not need to have an extremely high gain.

As the missile 22 approaches the target 21, the gradually increasing voltage at the output of the gain control voltage source 116 causes the gain of the variable gain amplifier 115 to gradually increase, thereby increasing the amplitude of the error signal, so that the missile 22 does not undercorrect for errors as it approaches the target 21.

Thus, there has been described an automatic missile guidance system that is small in size, light in weight, relatively inexpensive, and simple to operate. The missile guidance system of the present invention includes infrared tracking equipment of a simple, yet effective type, that is relatively insensitive to background radiation from the sun and other intense sources.

What is claimed is:

1. An automatic missile guidance system for guiding a missile along a line-of-sight to a target established by a human operator, said missile having guidance means comprising:

- a guidance unit for developing steering signals related to the deviation of said missile from said line-of-sight;
- means for transmitting said guidance signals from said guidance unit to said missile; and
- a source of pulsating radiant energy on said missile and directed to the rear thereof, said source of radiant energy having a predetermined pulsation frequency, said guidance unit being selectively responsive to said radiant energy at said predetermined pulsation frequency.

2. The automatic missile guidance system of claim 1 wherein said guidance unit has means for narrowing its field of view when said missile is proximate to said line-of-sight.

3. The automatic missile guidance system of claim 2 wherein said guidance unit has a radiant energy receiver thereon adapted to receive radiant energy from said source of pulsating radiant energy on said missile, said radiant energy receiving means having a large radiant energy detector disposed therein to receive radiant energy in any part of the field of view and a small radiant energy detector disposed therein, said small radiant energy detector being positioned to receive radiant energy in the central portion of the field of view of said radiant energy receiver, and switch means for switching between said large and said small radiant energy detectors in response to position of missile source image in field of view.

4. The automatic missile guidance system of claim 3 wherein said small radiant energy detector means has an output to said switch means to switch said switch means so that its small radiant energy detector means is switched to control said missile when the input radiance to said small radiant energy detection means exceeds a predetermined value.

5. The automatic missile guidance system of claim 4 wherein said source of pulsating radiant energy on said missile operates at a substantially constant frequency.

6. The automatic missile guidance system of claim 5 wherein said radiant energy receiving means on said guidance unit comprises a telescope having a wide field of view about an optical axis, a reticle disposed at the focus of said telescope concentric with and transverse to the axis thereof, means rotating said reticle about the axis of said telescope at a predetermined speed, said reticle having an opaque modulation pattern thereon to provide a substantially sinusoidally varying average transmissivity gradient circularly around said reticle and to provide a rapidly increasing depth-of-modulation gradient outward from the center of said reticle, said large radiant energy detector being disposed to receive radiant energy passed by said reticle, said small radiant energy detector being disposed in a position to intercept radiant energy passing through the central portion of said reticle.

7. The automatic missile guidance system of claim 3 wherein the output of said switch is connected to first and second phase detectors, for respectively detecting pitch and yaw of said missile, said phase detectors being connected to said missile to guide said missile.

8. The automatic missile guidance system of claim 7 wherein said means for transmitting said guidance signals from said guidance unit to said missile comprises at least one wire interconnected between said guidance unit and said missile.

9. An automatic missile guidance system for guiding a missile along a line-of-sight to a target established by a human operator, said missile having guidance means comprising:

- a guidance unit for developing steering signals related to the deviation of said missile from said line-of-sight;
- means for transmitting said guidance signals from said guidance unit to said missile; and
- a source of pulsating radiant energy on said missile and directed to the rear thereof, said source of

radiant energy having a predetermined substantially constant pulsation frequency, said guidance unit being selectively responsive to said radiant energy at said predetermined substantially constant pulsation frequency, said guidance unit having means for narrowing its field of view when said missile is proximate to said line-of-sight.

10. A system for guiding a self-propelled missile having steering means comprising:

means disposed on said missile for emitting radiant energy pulsating at a predetermined frequency rearwardly thereof;

means for intercepting radiant energy having a wide field of view;

means disposed within said interception means for amplitude modulating intercepted radiant energy at a predetermined frequency;

a large radiant energy detector disposed to receive radiant energy intercepted by said interception means and modulated by said modulation means;

a small radiant energy detector disposed within said interception means in a position to receive radiant energy in the central portion of the field of view of said interception means and modulated by said modulation means;

switch means having inputs electrically coupled to said radiant energy detectors and normally passing to its output only signals appearing at the output of said large radiant energy detector, said switch means being responsive to a switching signal applied at a control input for passing to its output only signals appearing at the output of said small radiant energy detector;

first frequency selective means having its input electrically coupled to said small radiant energy detector and having a narrow frequency passband centered around said predetermined frequency, said switch means having its control input electrically coupled to the output of said first frequency selective means;

second frequency selective means having its input coupled to the output of said switch means and having a narrow frequency passband centered around said predetermined frequency;

an amplitude modulation demodulator having its input coupled to the output of said second frequency selective means;

phase detecting means having an input coupled to the output of said demodulator;

reference means associated with said modulation means for developing periodic reference signals, the phase of which is related to the phase of said modulation means, said reference signals being coupled to the reference input of said phase detecting means; and

signal transmission means having its input coupled to the outputs of said phase detecting means and its output coupled to said missile.

11. A guided missile system comprising:

a self-propelled missile having steering means;

a source of infrared energy pulsating at a substantially constant predetermined frequency disposed on said missile and directed rearwardly thereof;

a visual telescope having an optical axis;

an infrared telescope having an optical axis substantially aligned with the optical axis of said visual telescope and having a wide field of view;

a reticle disposed at the focus of said infrared telescope concentric with and transverse to the axis thereof;

means for rotating said reticle about the axis of said infrared telescope at a predetermined speed, said reticle being transparent to said pulsating infrared energy and having an opaque coating arranged in a modulation pattern thereon, said coating being disposed in a sinusoidally varying concentration circularly around said reticle to provide a sinusoidal average transmissivity gradient circularly around said reticle, said coating being disposed in a varying radial concentration increasing outwardly to provide a rapidly increasing depth-of-modulation gradient near the center of said reticle;

a condensing lens disposed adjacent said reticle;

a large radiant energy detector disposed to receive radiant energy intercepted by said infrared telescope and passed by said reticle and said condensing lens;

a light pipe disposed in the center of said condensing lens to intercept radiant energy passing through the central portion of said reticle;

a small radiant energy detector disposed in said light pipe in a position to receive radiant energy intercepted thereby;

an electromagnetic relay having a normally open contact;

a normally closed contact;

a switch arm and an actuating coil, said small radiant energy detector being electrically coupled to the normally open contact of said relay, said large radiant energy detector being electrically coupled to the normally closed contact of said relay;

a first narrowband amplifier having its input electrically coupled to said small radiant energy detector and having a narrow passband centered around said predetermined frequency;

a rectifier and filter connected to the output of said first narrowband amplifier, said filter having a predetermined charge and discharge time constant;

a switch amplifier having its input electrically coupled to the output of said rectifier and filter and having its output connected to the actuating coil of said relay, said switch amplifier being biased to have a predetermined input threshold level above which said relay is energized and below which said relay is de-energized;

a source of voltage that exceeds said threshold a predetermined time after the launching of said missile electrically coupled to the input of said switch amplifier;

a second narrowband amplifier having its input coupled to the switch arm of said relay and having a narrow passband centered around said predetermined frequency;

an automatic gain control circuit coupled to said second narrowband amplifier for maintaining signals at the output thereof at a constant amplitude;

an amplitude modulation demodulator having its input coupled to the output of said second narrowband amplifier;

a variable gain amplifier having its input coupled to the output of said demodulator, said variable gain amplifier having a gain that varies as a function of an applied control voltage;

a gain control voltage source coupled to said variable gain amplifier and applying a control voltage thereto that gradually increases the gain of said variable gain amplifier from the time said missile is launched;

a pair of phase detectors, each having signal inputs coupled to the output of said variable gain amplifier;

a pair of coil and magnet assemblies associated with said reticle for developing periodic reference signals having phases related to the instantaneous angular position of said reticle, said reference signals being in phase quadrature with each other;

a pair of squaring circuits, each having its input individually coupled to the output of a different one of said coil and magnet assemblies, the output of each of said squaring circuits being individually coupled to the reference input of a different one of said phase detectors;

a pair of compensation networks, each having its input coupled to the output of a different one of said phase detectors; and

a signal transmission circuit having its input coupled to the outputs of said compensation networks and its output coupled to said missile.

12. A system for guiding a self-propelled missile having steering means comprising:

a source of infrared energy pulsating at a predetermined frequency disposed on said missile and directed rearwardly thereof;

an infrared telescope having a wide field of view about an optical axis;

a reticle disposed at the focus of said infrared telescope concentric with and transverse to the axis thereof;

means for rotating said reticle about the axis of said infrared telescope at a predetermined speed, said reticle being transparent to said pulsating infrared energy and having an opaque coating arranged in a modulation pattern thereon, said coating being disposed in a sinusoidally varying concentration circularly around said reticle to provide a sinusoidal average transmissivity gradient circularly around said reticle, said coating being disposed in a varying radial concentration increasing outwardly to provide a rapidly increasing depth-of-modulation gradient near the center of said reticle;

a condensing lens disposed adjacent said reticle;

a large radiant energy detector disposed to receive radiant energy intercepted by said infrared telescope and passed by said reticle and said condensing lens;

a light pipe disposed in the center of said condensing lens to intercept radiant energy passing through the central portion of said reticle;

a small radiant energy detector disposed in said light pipe in a position to receive radiant energy intercepted thereby;

switch means having inputs electrically coupled to said radiant energy detectors and normally passing only signals appearing at the output of said large radiant energy detector, said switch means being responsive to an applied switching signal for passing only signals appearing at the output of said small radiant energy detector;

a first narrowband amplifier having its input electrically coupled to said small radiant energy detector and having a narrow passband centered around said predetermined frequency;

a rectifier and filter connected to the output of said first narrowband amplifier, said filter having a predetermined charge and discharge time constant;

a switch amplifier having its input electrically coupled to the output of said rectifier and filter and having its output connected to the control input of said switch means, said switch amplifier being biased to have a predetermined input threshold level above which said switch means is responsive and below which said switch means is nonresponsive;

a source of voltage that exceeds said threshold a predetermined time after the launching of said missile electrically coupled to the input of said switch amplifier;

a second narrowband amplifier having its input coupled to the output of said switch means and having a narrow passband centered around said predetermined frequency;

an automatic gain control circuit coupled to said second narrowband amplifier for maintaining signals at the output thereof at a constant amplitude;

an amplitude modulation demodulator having its input coupled to the output of said second narrowband amplifier;

a variable gain amplifier having its input coupled to the output of said demodulator, said variable gain amplifier having a gain that varies as a function of an applied control voltage;

a gain control voltage source coupled to said variable gain amplifier and applying a control voltage thereto that gradually increases the gain of said variable gain amplifier from the time said missile is launched;

a pair of phase detectors, each having signal inputs coupled to the output of said variable gain amplifier;

reference means associated with said reticle for developing a pair of periodic reference signals having phases related to the instantaneous angular position of said reticle, said reference signals being in phase quadrature with each other, each of said reference signals developed by said reference means being individually coupled to the reference input of a different one of said phase detectors;

a pair of compensation networks, each having its input coupled to the output of a different one of said phase detectors; and

a signal transmission circuit having its input coupled to the outputs of said compensation networks and its output coupled to said missile.

13. A system for guiding a self-propelled missile having steering means comprising:

a source of infrared energy pulsating at a substantially constant predetermined frequency disposed on said missile and directed rearwardly thereof;

an infrared telescope having a wide field of view about an optical axis;

a reticle disposed at the focus of said infrared telescope concentric with and transverse to the axis thereof;

means for rotating said reticle about the axis of said infrared telescope at a substantially constant predetermined speed, said reticle being transparent to said pulsating infrared energy and having an opaque coating arranged in a modulation pattern thereon, said coating being disposed in a sinusoidally varying concentration circularly around said reticle to provide a sinusoidal average transmissivity gradient circularly around said reticle, said coating being disposed in a varying radial concentration increasing outwardly to provide a rapidly increasing depth-of-modulation gradient near the center of said reticle;

a condensing lens disposed adjacent said reticle;

a large radiant energy detector disposed to receive radiant energy intercepted by said infrared telescope and passed by said reticle and said condensing lens;

a light pipe disposed in the center of said condensing lens to intercept radiant energy passing through the central portion of said reticle;

a small radiant energy detector disposed in said light pipe in a position to receive radiant energy intercepted thereby;

switch means having inputs electrically coupled to said radiant energy detectors and normally passing to its output only signals appearing at the output of said large radiant energy detector, said switch means being responsive to a switching signal applied at a control input for passing only signals appearing at the output of said small radiant energy detector;

a first narrowband amplifier having its input electrically coupled to said small radiant energy detector and having a narrow passband centered around said predetermined frequency;

a rectifier and filter connected to the output of said first narrowband amplifier, said filter having a predetermined charge and discharge time constant, said switch means having its control input electrically coupled to the output of said rectifier and filter;

a source of voltage that exceeds said threshold a predetermined time after the launching of said missile electrically coupled to the control input of said switch means;

a second narrowband amplifier having its input coupled to the output of said switch means and having a narrow passband centered around said predetermined frequency and having an automatic gain control for maintaining signals at the output thereof at a substantially constant amplitude;

an amplitude modulation demodulator having its input coupled to the output of said second narrowband amplifier;

a variable gain amplifier having its input coupled to the output of said demodulator, said variable gain

amplifier having a gain that gradually increases from the time said missile is launched;

a pair of phase detectors, each having signal inputs coupled to the output of said variable gain amplifier;

reference means associated with said reticle for developing a pair of periodic reference signals having phases related to the instantaneous angular position of said reticle, said reference signals being in phase quadrature with each other, each of said reference signals developed by said reference means being individually coupled to the reference input of a different one of said phase detectors; and

a signal transmission circuit having its input coupled to the outputs of said phase detectors and its output coupled to said missile.

14. A system for guiding a self-propelled missile having steering means comprising:

a source of infrared energy pulsating at a substantially constant predetermined frequency disposed on said missile and directed rearwardly thereof;

an infrared telescope having a wide field of view about an optical axis;

a reticle disposed at the focus of said infrared telescope concentric with and transverse to the axis thereof;

means for rotating said reticle about the axis of said infrared telescope at a substantially constant predetermined speed, said reticle having an opaque modulation pattern thereon to provide a sinusoidal average transmissivity gradient circularly around said reticle and to provide a rapidly increasing depth-of-modulation gradient near the center of said reticle;

a condensing lens disposed adjacent said reticle;

a large radiant energy detector disposed to receive radiant energy intercepted by said infrared telescope and passed by said reticle and said condensing lens;

a light pipe disposed in the center of said condensing lens to intercept radiant energy passing through the central portion of said reticle;

a small radiant energy detector disposed in said light pipe in a position to receive radiant energy intercepted thereby;

switch means having inputs electrically coupled to said radiant energy detectors and normally passing to its output only signals appearing at the output of said large radiant energy detector, said switch means being responsive to a switching signal applied at a control input for passing only signals appearing at the output of said small radiant energy detector;

first frequency selective means having its input electrically coupled to said small radiant energy detector and having a narrow frequency passband centered around said predetermined frequency, said switch means having its control input electrically coupled to the output of said first frequency selective means;

a source of voltage that exceeds a predetermined value a predetermined time after the launching of said missile electrically coupled to the control input of said switch means;

second frequency selective means having its input coupled to the output of said switch means and having a narrow frequency passband centered around said predetermined frequency and having an automatic gain control for maintaining signals at the output thereof at a substantially constant amplitude;

an amplitude modulation demodulator having its input coupled to the output of said second frequency selective means;

a variable gain amplifier having its input coupled to the output of said demodulator, said variable gain amplifier having a gain that gradually increases from the time said missile is launched;

phase detecting means having an input coupled to the output of said variable gain amplifier;

reference means associated with said reticle for developing a pair of periodic reference signals having phases related to the instantaneous angular position of said reticle, said reference signals being in phase quadrature with each other, said reference signals being coupled to the reference input of said phase detecting means; and

a signal transmission circuit having its input coupled to the outputs of said phase detecting means and its output coupled to said missile.

15. A system for guiding a self-propelled missile having steering means comprising:

a source of infrared energy pulsating at a predetermined frequency disposed on said missile and directed rearwardly thereof;

an infrared telescope having a wide field of view about an optical axis;

a reticle disposed at the focus of said infrared telescope concentric with and transverse to the axis thereof;

means for rotating said reticle about the axis of said infrared telescope at a predetermined speed, said reticle having an opaque modulation pattern thereon to provide a sinusoidally varying average transmissivity gradient circularly around said reticle and to provide a rapidly increasing depth-of-modulation gradient outward from the center of said reticle;

a large radiant energy detector disposed to receive radiant energy intercepted by said infrared telescope and passed by said reticle;

a small radiant energy detector disposed in said infrared telescope in a position to intercept radiant energy passing through the central portion of said reticle;

switch means having inputs electrically coupled to said radiant energy detectors and normally passing to its output only signals appearing at the output of said large radiant energy detector, said switch means being responsive to a switching signal applied at a control input for passing only signals appearing at the output of said small radiant energy detector;

first frequency selective means having its input electrically coupled to said small radiant energy detector and having a narrow frequency passband centered around said predetermined frequency, said switch means having its control input electrically coupled to the output of said first frequency selective means;

second frequency selective means having its input coupled to the output of said switch means and having a narrow frequency passband centered around said predetermined frequency;

an amplitude modulation demodulator having its input coupled to the output of said second frequency selective means;

a variable gain amplifier having its input coupled to the output of said demodulator and having a gain that gradually increases from the time said missile is launched;

phase detecting means having an input coupled to the output of said variable gain amplifier;

reference means associated with said reticle for developing periodic reference signals, the phase of which is related to the instantaneous angular position of said reticle, said reference signals being coupled to the reference input of said phase detecting means; and

a signal transmission circuit having its input coupled to the outputs of said phase detecting means and its output coupled to said missile.

16. A system for guiding a self-propelled missile having steering means comprising:

a source of infrared energy pulsating at a predetermined frequency disposed on said missile and directed rearwardly thereof;

an infrared telescope, having a wide field of view about an optical axis;

a reticle disposed at the focus of said infrared telescope concentric with and transverse to the axis thereof;

means for rotating said reticle about the axis of said infrared telescope at a predetermined speed, said reticle having an opaque modulation pattern thereon to provide a sinusoidally varying average transmissivity gradient circularly around said reticle and to provide a rapidly increasing depth-of-modulation gradient outward from the center of said reticle;

a large radiant energy detector disposed to receive radiant energy intercepted by said infrared telescope and passed by said reticle;

a small radiant energy detector disposed in said infrared telescope in a position to intercept radiant energy passing through the central portion of said reticle;

switch means having inputs electrically coupled to said radiant energy detectors and normally passing to its output only signals appearing at the output of said large radiant energy detector, said switch means being responsive to a switching signal applied at a control input for passing to its output only signals appearing at the output of said small radiant energy detector;

first frequency selective means having its input electrically coupled to said small radiant energy detector and having a narrow frequency passband centered around said predetermined frequency, said switch means having its control input electrically coupled to the output of said first frequency selective means;

second frequency selective means having its input coupled to the output of said switch means and having a narrow frequency passband centered around said predetermined frequency;

an amplitude modulation demodulator having its input coupled to the output of said second frequency selective means;

phase detecting means having an input coupled to the output of said demodulator;

reference means associated with said reticle for developing periodic reference signals, the phase of which is related to the instantaneous angular position of said reticle, said reference signals being coupled to the reference input of said phase detecting means; and

a signal transmission circuit having its input coupled to the outputs of said phase detecting means and its output coupled to said missile.

17. An interrupted radiation source comprising:

a radiating member having a radiating surface;

means adjacent said member for heating said radiating surface;

driving means disposed adjacent said radiating member and having a shaft spaced away from and generally parallel to said radiating surface; and

a plane interruption member of substantially the same size and shape as said radiating member and mechanically coupled at its edge to the shaft of said driving means for rotation thereby about an axis parallel with the plane surfaces of said interruption member, said interruption member being disposed to shield said radiating member twice during each revolution about said axis.

18. An interrupted radiation source comprising:

a cylindrical housing sealed at one end by a heat-resistant disk;

a pyrotechnic composition disposed inside said housing;

an electrically operated firing squib disposed inside said housing in contact with said pyrotechnic composition;

at least one piece of iron within said housing and embedded in said pyrotechnic composition;

a speed-regulated motor secured to the outside of said housing and having its shaft spaced away from and parallel to the plane outer surface of said heat-resistant disk; and

an interruption disk of substantially the same size as said heat-resistant disk and mechanically coupled at its circumference to the shaft of said motor for rotation thereby about an axis parallel with the plane surfaces of said interruption disk, said interruption disk being disposed to shield said heat-resistant disk twice during each revolution about said axis.

19. An interrupted radiation source comprising:

a cylindrical housing sealed at one end by a molybdenum disk having a zirconium carbide coating;

a pyrotechnic composition disposed inside said housing and composed of 56 percent iron oxide, 14 percent aluminum powder, 3 percent boron and 27 percent barium chromate;

an electrically operated firing squib disposed inside said housing in contact with said pyrotechnic composition;

at least one piece of iron within said housing and embedded in said pyrotechnic composition;

a speed-regulated motor secured to the outside of said housing and having its shaft spaced away from

and parallel to the plane outer surface of said molybdenum disk; and

an interruption disk of substantially the same size as said molybdenum disk and mechanically coupled at its circumference to the shaft of said motor for rotation thereby about an axis parallel with the plane surfaces of said interruption disk, said interruption disk being disposed to shield said molybdenum disk twice during each revolution about said axis.

20. A reticle for amplitude modulating radiant energy comprising:

a disk transparent to said radiant energy;
a coating opaque to said radiant energy disposed on said disk in a pattern, said pattern comprising concentric circular opaque lines having a progressively varying width around said disk, increasing from a minimum at a first radial zone on said disk to a maximum at a second radial zone on said disk and decreasing to said minimum at said first radial zone, said first and second zones being 180° opposed.

21. A reticle for amplitude modulating radiant energy comprising:

a disk transparent to said radiant energy;
a coating opaque to said radiant energy disposed on said disk in a pattern, said pattern comprising concentric circular opaque lines having a progressively varying width around said disk, increasing from a minimum at a first radial zone on said disk to a maximum at a second radial zone on said disk and decreasing to said minimum at said first radial zone, said first and second zones being 180° opposed, said concentric circular opaque lines having a progressively increasing maximum width from the center of said disk to the circumference thereof, the spacing between adjacent ones of said concentric circular opaque lines in said second zone progressively decreasing from the center of said disk to the circumference thereof.

22. A radiant energy telescope having dual, concentric fields of view comprising:

a cylindrical outer case having an entrance window at one end thereof;

first and second objective lenses having a wide field of view and disposed within said case adjacent said window;

a transparent image surface disposed within said case at the focus of said objective lens;

a condensing lens disposed within said case adjacent said image surface;

a large radiant energy detector disposed within said case at a location to receive radiant energy focused on said image surface and passed by said condensing lens;

a light pipe disposed in the center of said condensing lens to intercept radiant energy passing through the central portion of said image surface; and

a small radiant energy detector disposed within said light pipe in a position to receive radiant energy intercepted thereby.

23. In an infrared tracker, apparatus for developing a signal indicative of the instantaneous angular position of a modulating reticle, said apparatus comprising:

a cylindrical reticle holder of nonmagnetic material rotatably disposed in said infrared tracker and containing said modulating reticle;

driving means mechanically coupled to said reticle holder for rotation thereof;

a band of magnetic material fixed to the outside of said reticle holder, said band varying linearly in width from a maximum width to a minimum width;

a pair of magnetic pole pieces, each disposed with an edge adjacent said band, the width of the adjacent edges of said pole pieces being substantially equal to the maximum width of said band;

a permanent magnet having each of its poles individually magnetically coupled to a different one of said pole pieces; and

a coil of wire wound around said permanent magnet.

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