A missile guidance system using a laser beam and comprising, in a ground station, optical means having an optical axis for aiming at said device; a laser beam transmitter and a laser beam receiver having parallel axes, means for measuring the angular difference between said optical and parallel axes, means for measuring other angular differences defining the position of the missile with respect to the transmitted laser beam; means for deducing from the measurement of first-named angular difference tracking orders for the missile; and means for deriving navigation control signals from all said angular differences and for transmitting said control signals to said missile via said transmitted laser beam.

3 Claims, 7 Drawing Figures
Fig. 4
INFRARED CONTROL SYSTEM FOR MISSILE TELEGUIDING

This invention relates to a system for the guidance by remote control of self-propelled missiles towards a target from a sighting and firing station which also controls the missile path. For instance, the missile can in a weapon system have an explosive charge and be of use for attacking moving ground vehicles under the control of a ground firing station.

In a prior art system of this kind, the missile control instructions were deduced from the angular difference between the sighting direction of the missile seen from the sighting station and the direction from the aiming station to the target. To find out this difference, means for locating the missile were placed beside the aiming line of sight for the target, the axes of the missile locator and of the target aiming device being kept parallel to one another. The missile had at its rear tracers emitting an infra-red radiation, and the missile locator had a lens which forms at its focal point the image of the missile tracers on the sensitive surface of a photodetector element. A light modulator was disposed in the missile locator and having the form of a rotating disk having equal and alternate transparent and opaque sectors, the disk center sweeping a circular orbit around the infra-red optical axis, modulates the infra-red beam received from the missile. The photodetector element therefore delivered a frequency-modulated alternating current whose frequency swing and phase (the phase being defined as the time of appearance of the maximum or minimum frequency relatively to an origin of the cycle) depend upon the difference between the coordinates of the tracer-produced image and the optical axis of the locator. Designating by \( \beta \) the angle between the observer to missile direction and the observer to target direction, an electronic circuit produced signals proportional to \( \cos \beta \) and to \( \sin \beta \) respectively and these signals were retransmitted electrically to the missile and acted on the direction control elements thereof. A control loop extending from the missile to the aiming station and back to the missile was therefore provided which kept the missile on the target direction. The U.S. Pat. specification No. 2,967,247 discloses the operation of the light modulator. It is well known that the function of the tracers is to increase the range of the teleguidance system by increasing the contrast between the missile and its environment. However, in some circumstances many very bright spots may appear in the field of the teleguidance system, with the result of infra-red dazzle and misses.

There are other problems connected with retransmission to the missile of the ground signals prepared in dependence upon the instantaneous value of the angular difference between the observer to missile direction and the observer to target direction. If radio waves are used, secrecy is sometimes unsatisfactory and the enemy may effectively interfere. If conductive wires are attached to the missile, the same cannot travel faster than the fastest speed at which the wires can unwind satisfactorily, and so wired systems are unsuitable for modern fast missiles.

It is also known for the firing station to have a source which can be modulated by the brightness of the missile and for the same to have optical reflectors such as catadiopeters or totally reflecting tetrahedric prisms. The rear of the missile then becomes a secondary source of modulated radiation which helps to improve the performance of the missile locator.

In the system according to the invention, a light source of this kind can, with advantage, be an infra-red laser, simply because an infra-red laser can be modulated simultaneously by a wide frequency band of signals serving as control signals and by low-frequency sinusoidal missile identification signals. Control signals can therefore be transmitted to the missile by modulation of the laser beam. The system gives some secrecy in the transmission of tracking orders and helps to protect the tele-guidance system from interference.

The rear of the missile therefore has an optical reflecting surface for the doubly modulated infra-red light transmitted by the firing-station laser, plus photodetector means for such light. The missile has movement control by signals collected at the output of a chain of electronic circuits connected to the photodetector cell or means, the same being disposed in a non-reflecting part at the rear of the missile, the chain of electronic circuits comprising at least one detector of the control signals which modulate the received infra-red light.

The beam of the laser at the firing station tracks the missile under the control of known control means. Disposed at the firing station beside the light source is a receiver for the infra-red radiation reflected by the rear of the missile, the receiver forming part of the missile locator, the optical axes of the light source and of the receiver being parallel to one another and rigidly associated with one another. The receiver energizes the beam tracking control system which processes the incoming data into tracking control signals acting on the common direction of the latter optical axes.

One way of producing these modulations is to combine with the laser a modulator, such as a Pockels effect modulator, which modulates the laser beam simultaneously with low-frequency sinusoidal wave serving to identify reflected radiation from the missile with and the missile navigation control signals. The latter signals are supplied by a computer on the basis of incoming data — i.e., on the basis of the signals delivered by the receiver and on the basis of the measured angle between the direction of the aforesaid common optical axis and the direction of the target sighting axis taking due account of the observer-to-missile distance determined, e.g., by a timer which starts up at the departure of the missile, whose variation of the speed in relation to time is known.

The invention will now be described in detail with reference to the accompanying drawings wherein:

FIG. 1 is a geometric diagram to explain the system for tele-guidance of a missile towards a target according to the invention;

FIG. 2 shows the light modulator of the tracking and locating facility;

FIGS. 3a and 3b are diagrams of signal wave forms to help explain FIG. 2;

FIG. 4 shows the ground teleguidance system;

FIG. 5 shows the mounting frame, with two degrees of freedom, of a laser beam transmitting and receiving mirror and of the sighting means, and

FIG. 6 shows the missile direction control circuits.

Referring to FIG. 1, there can be seen a flying missile \( E \), a target \( C \) moving along trajectory or path \( T \) and a coordinate system \( Oxyz \), \( O \) denoting the aiming, firing and control station. The plane \( xOy \) is such as to contain
the straight line $OC$. The missile $E$ is projected on the plane $xOy$ at a place $E_{xOy}$ and on the straight line $OC$ at a point $E$.

The angle $a = EOC$ is the angular difference between the observer-to-missile direction and the observer-to-target direction. The length of the straight line $eE$ represents the distance separating the missile from the aiming axis. This distance can be broken down into two components $X$ and $Y$, $X$ being perpendicular to the aiming axis $OC$ and $Y$ being perpendicular to the $xOy$.

The forces which the steering gear must apply to the missile are proportional to $\cos b$ and $\sin b$, $b$ being the angle shown in FIG. 1.

FIG. 2 shows the light modulator of the tracker and locator, as is apparent, the light modulator is placed before a detector cell (photo-detector) and rotates in front of the photocathode thereof. It is assumed in FIG. 2 that the light modulator is stationary and that the image of the missile describes a circle. The reference direction $pp1$ is parallel to the straight line $E_{xOy}$ of FIG. 1. The point $M$ is the image of the missile assumed to be in alignment with the observer-to-missile direction, while the point $M'$ is the image of the missile assumed to be out of alignment with such direction. The signal which is shown in FIG. 3a and which is a constant-frequency rectangular wave signal corresponds to the point $M$, and the frequency-modulated signal of FIG. 3b corresponds to the point $M'$. Clearly, the frequency swing is a measure of the out-of-alignment angle of the missile — i.e., the apex angle of the cone whose axis is the infra-red beam axis and one generatrix of which passes through the missile, the interval between the time $t_{\text{m}}$ of the maximum or minimum of the instantaneous frequency and the time $t_{\text{m'}}$ at which the point $M'$ crosses the straight line $PP1$ measures the angle of rotation of such generatrix around the axis.

When the frequency swing and this period of time are nil simulataneously, the missile is aligned on the beam. If in addition the beam axis and aiming axis are parallel to one another, the missile is aligned on the target.

Referring now to FIGS. 4 and 5, there can be seen an infra-red CO$_2$ laser 10, a Pockels effect modulator 11, an optical beam collimator 12, reflecting mirrors 13, 14 and a large mirror 15 mounted with two degrees of rotational freedom — one for bearing and one for elevation — in an appropriate mechanical system. Rigs in which only the mirror for transmitting and receiving the laser beam can rotate with $2^\circ$ of freedom and in which the actual laser and the light receiver are stationary are familiar in the art and need not be described in detail here. Mirror 15 transmits the laser beam to the missile $E$. The beam is reflected by the missile rear reflector and directed by mirror 15 to a parabolic reflecting mirror 16 which focuses the beam at its focal point. A mirror 17 reflects the beam through an infra-red filter 20 towards a direction detection cell 21. Disposed therebetween is the light modulator 22 which has been described with reference to FIG. 2 and whose rotational axis sweeps a uniform circular orbit around the center of the photocathode of cell 21.

A low-frequency sinusoidal generator 24 is connected to the laser modulator 11.

Advantageously, the photo-sensitive surface of cell 21 is composed of a mixture of mercury and cadmium tellurides. The signal output by cell 21 goes to a computer 26 which also receives the bearing and elevation angle signals of mirror 15 and the signals for the corresponding angles of the aiming axis of the sight 39 (FIG. 5), the reception being through the agency of position sensors 27–30 which are disposed, i.e., through the agency of universal suspensions, on the bearing and elevation shafts. From these data the computer 26 calculates the angle $a$, the angle $b$, the components $\sin b$ and $\cos b$ and the bearing and elevation components of the beam corresponding to the conical differences (angle at the cone apex and angle around the cone of the ground-station-to-missile direction). The latter components are supplied to bearing and elevation servomotors 31, 32 respectively of mirror 15, and the components $\sin b$ and $\cos b$ are applied to an encoder 38 which converts them into binary code and which is connected to the modulator 11. Navigation instruction data are therefore transmitted to the missile by laser modulation.

Referring to FIG. 6, there can be seen at the rear of the missile a rear reflector 33 and a photodetector 34, the same being connected to a decoder 35 which is connected to two amplifiers 36, 37 operating in known manner the rudders and elevators respectively.

The invention has been described with reference to a complete embodiment, but variants which can readily be conceived by the skilled addressee are of course possible and fall under this invention as defined in the following claims. For instance, the tracking control loop, instead of comprising an error signal detector in the form of a light modulator associated with a detector cell, could comprise an error signal detector in the form of an image dissection detector cell.

What I claim is:

1. A teleguidance system for guiding a missile to a target by means of a laser beam and comprising, in a ground station: means for optically aiming at said target having an optical aiming axis; a laser beam transmitter and a laser beam receiver having parallel optical axes; means for measuring the angular difference between said optical aiming axis and parallel axes means for measuring other angular differences defining the position of said missile relatively to said optical axis of said transmitted laser beam; means for deriving from the measurement of the first-mentioned angular difference tracking orders for the missile, such orders acting in the direction common to said parallel axes; and means for deriving control signals from all such angular differences and for transmitting such signals via said laser beam transmitter to navigation control means provided on board the missile, characterized in that said missile has a rear reflector which reflects some of the light of said transmitted beam to said beam receiver where such light is received by a photodetector (21); and said beam transmitted by said transmitter is doubly modulated in a modulator (11) energized by a generator (24) of permanent modulating signals and by said photodetector (21) through a processing circuit (26, 38) for preparing control signals, the latter circuit being energized from said photodetector (21) and via connections (27–30, FIG. 4) fed from said means for measuring the angular difference between said aiming axis and parallel axes, so that said control signal processing circuit (26, 38) fed from said modulator (11) and connections (27–30) delivers to said modulator (11) said control signals transmitted to said on-board navigation control means.

2. A teleguidance system according to claim 1, characterized in that an on-board photodetector carried by
said missile energizes a chain of electronic circuits comprising at least one decoder of the modulation signals of the beam received by said photodetector, said decoder energizing said on-board navigation means.

3. A teleguidance system according to claim 1, characterized in that said processing circuit comprises a coder (38) converting signals output by a computer (26) in analog form into digital signals applied to said modulator (11); and said missile comprises a further photodetector energizing a decoder converting into analog signals the control signals received in digital form by said further photodetector.

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