United States Patent [19]

Crovella

[11] **3,796,396**

[45] **Mar. 12, 1974**

[54] **METHOD AND APPARATUS FOR MODULATING A PYROTECHNIC TRACER**

[76] Inventor: **Christian Crovella,** 9, rue de la Mediterranee, Antony, France

[22] Filed: **Oct. 30, 1972**

[21] Appl. No.: **301,761**

[30] **Foreign Application Priority Data**

Oct. 29, 1971 France 71.39125
Dec. 22, 1971 France 71.46235

[52] **U.S. Cl.** **244/3.14,** 244/3.11, 244/3.13
[51] **Int. Cl.** **F41g 7/14,** F41g 7/00
[58] **Field of Search** 244/3.1, 3.11, 3.12, 3.13, 244/3.14, 3.16, 3.23

[56] **References Cited**

UNITED STATES PATENTS

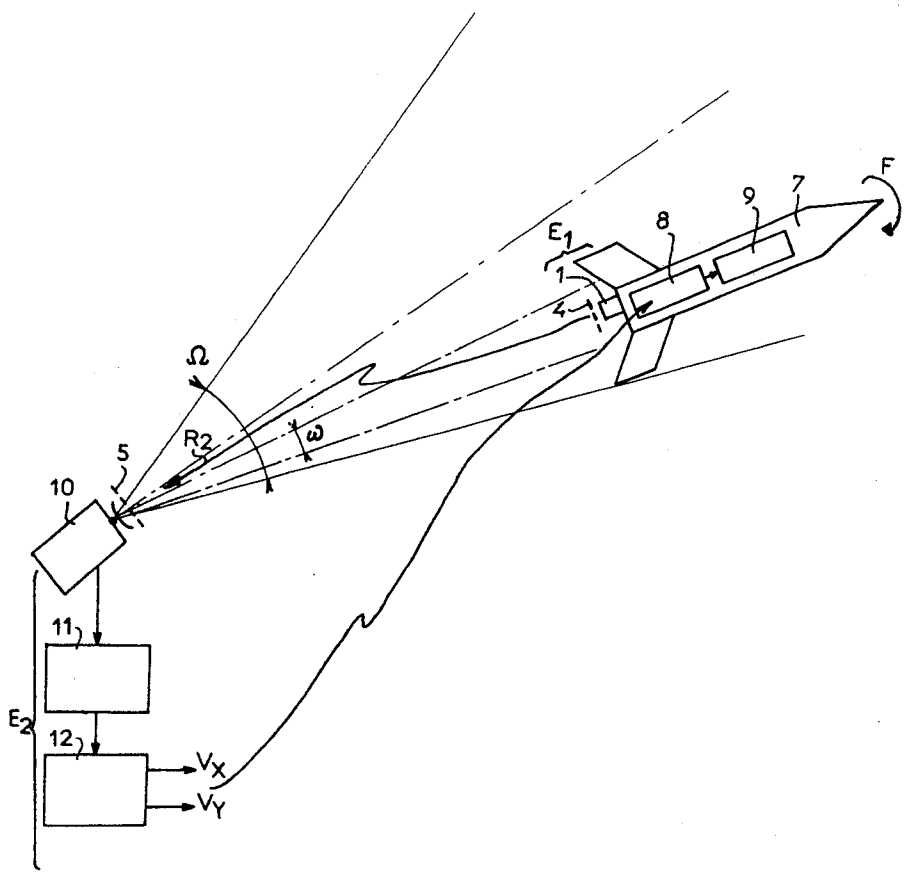
2,362,832	11/1944	Land	244/3.13
2,404,942	7/1946	Bedford	244/3.13
2,930,894	3/1960	Bozeman	244/3.11
2,995,749	8/1961	Robinson, Jr.	244/3.14
3,332,641	7/1967	Bezerie	244/3.12
3,338,534	8/1967	Girsberger	244/3.14
3,398,918	8/1968	Girault	244/3.13

Primary Examiner—Benjamin A. Borchelt
Assistant Examiner—C. T. Jordan
Attorney, Agent, or Firm—Karl W. Flocks

[57] **ABSTRACT**

A system for modulating the radiation emitted by a pyrotechnic source of the tracer type emitting neither gases nor particles and mounted on a spinning missile guided along an optical path by means of a ground-based receiver device, in order to improve the transmitted-signal/background noise ratio, in which said radiation emitter source is placed at the rear of the missile so that said radiation be emitted substantially along the spin axis of the missile as the same follows its trajectory and be filtered by means of a polarizing filter rotating with the missile; and in which a second polarizing filter is placed in the optical path of said ground-based receiver device, the effect of which is to pick up the circularly polarized radiation emitted by said first filter and cause it to be sinusoidally modulated at a frequency dependent on the resultant relative rotation speed between the two filters; It results that the ratio of the modulated signal emitted by the emitter source to the unmodulated said background noise is considerably increased and permits ready processing of the transmitted signal to allow optical command guidance of the missile.

16 Claims, 11 Drawing Figures



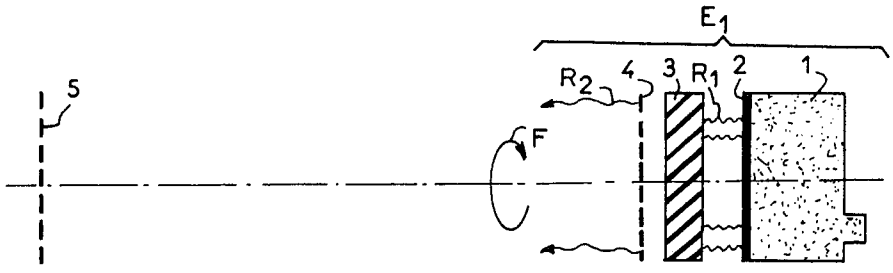


FIG.1

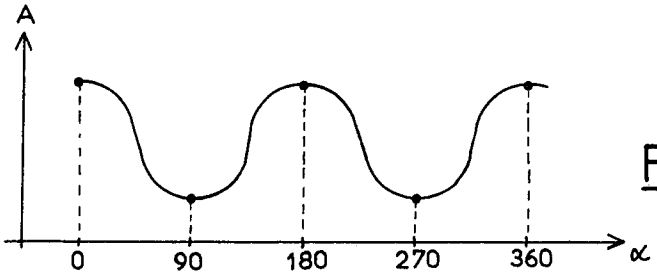


FIG. 2

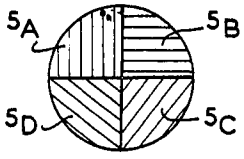


FIG. 4

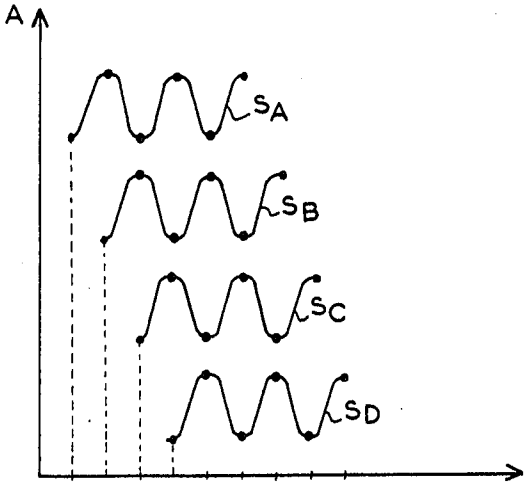


FIG. 5

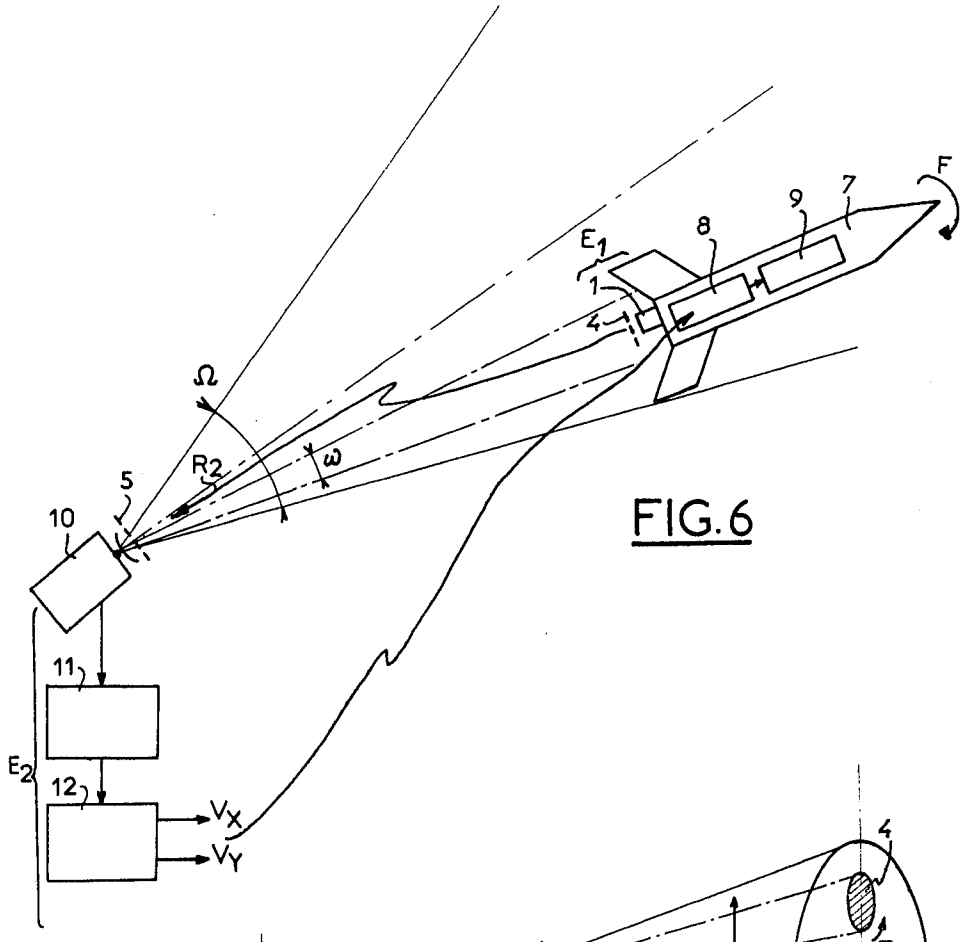


FIG.6

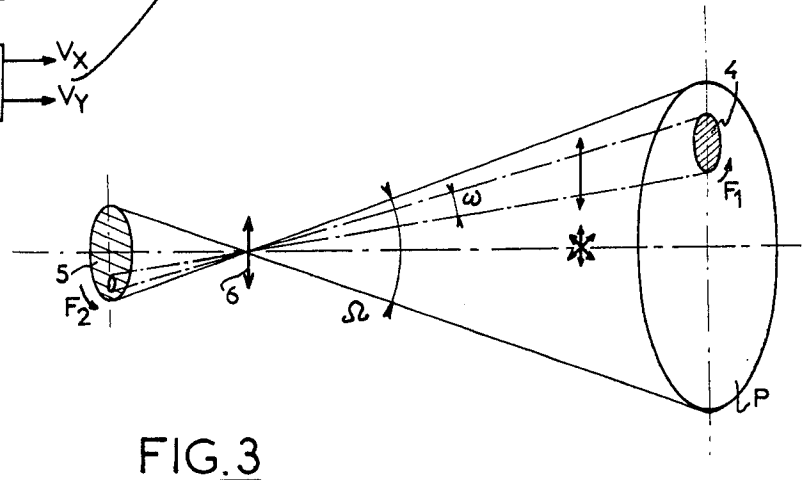


FIG.3

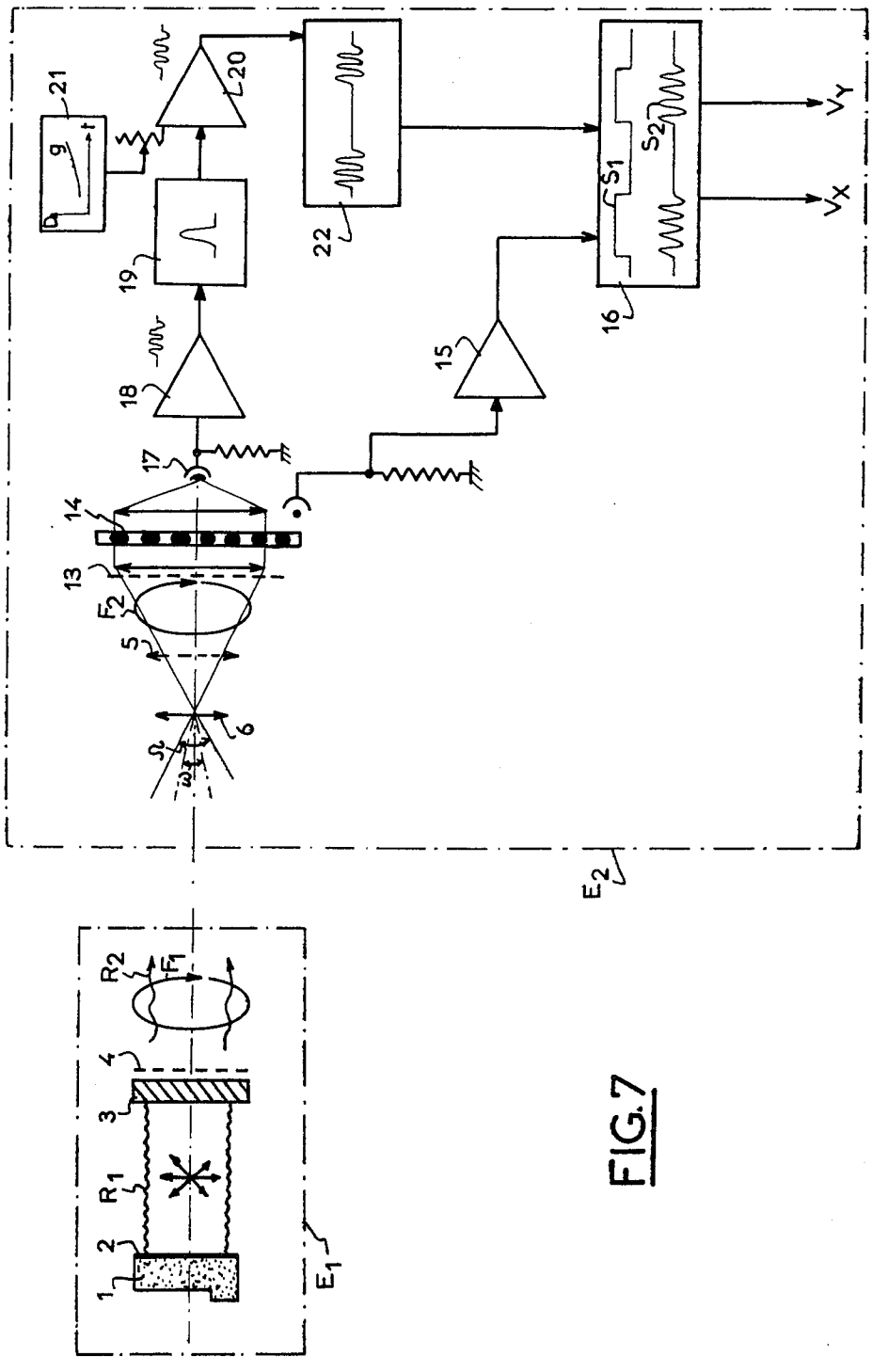


FIG.7

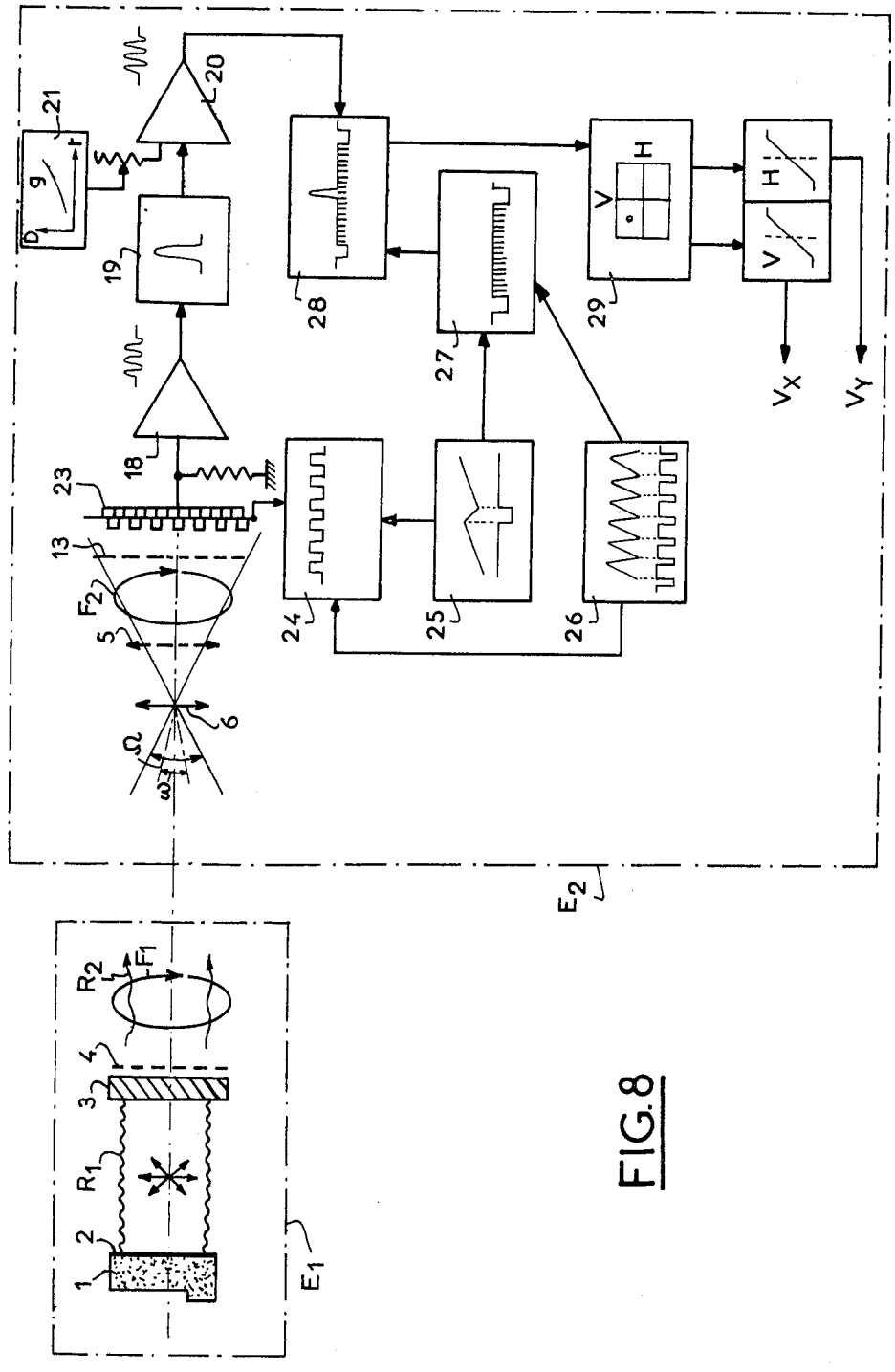

20
21
9
r
S
19
18
23
13
F2
5
6
Ω
ω
28
27
29
V
H
H
V
Vx
Vy
24
25
26
E2
R2
F1
4
3
R1
2
1
E1

FIG.8

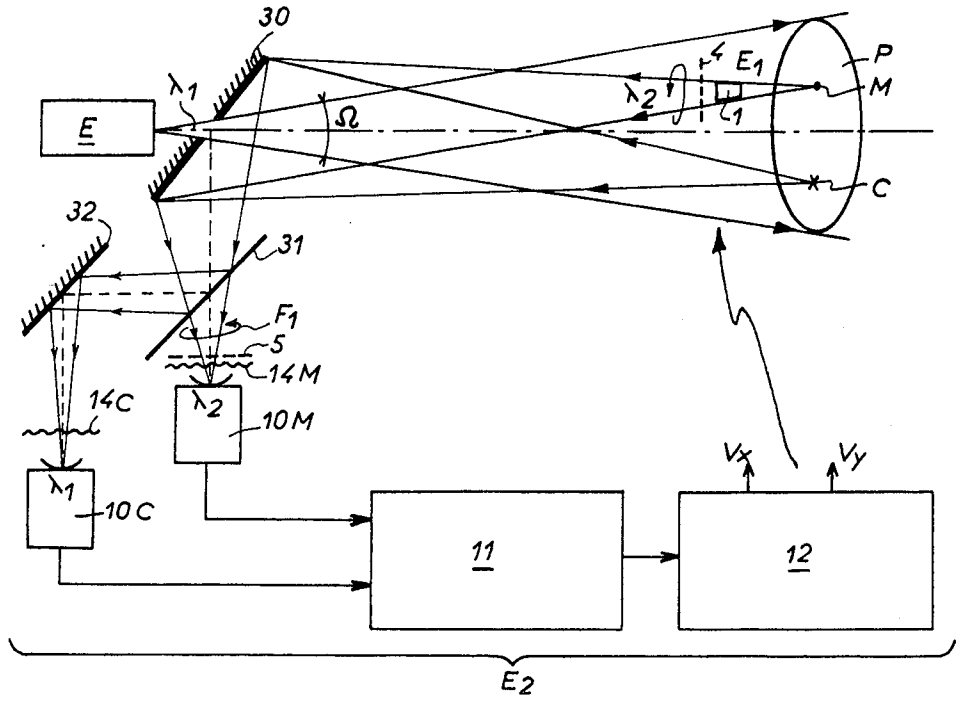


FIG. 9

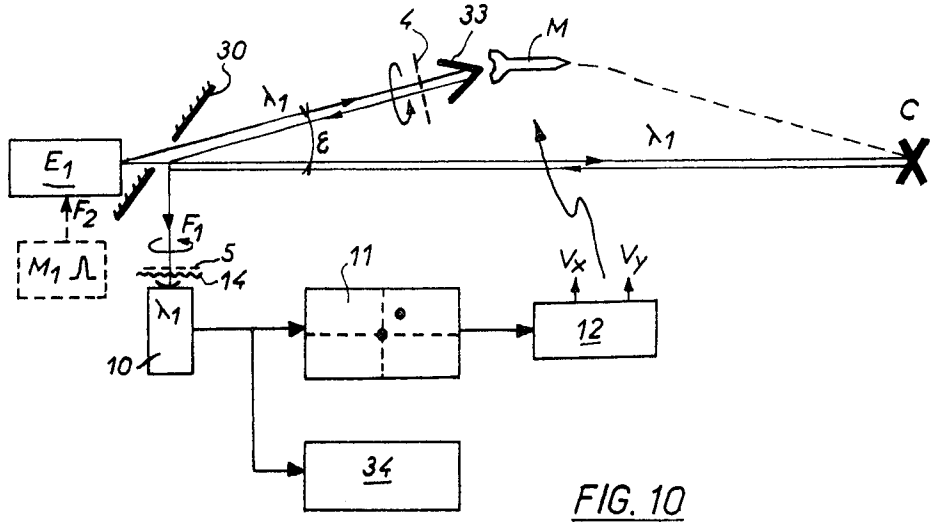

4
33
M
30
λ1
ε
C
λ1
E1
F2
F1
M1
5
14
11
Vx
Vy
λ1
12
10
34

FIG. 10

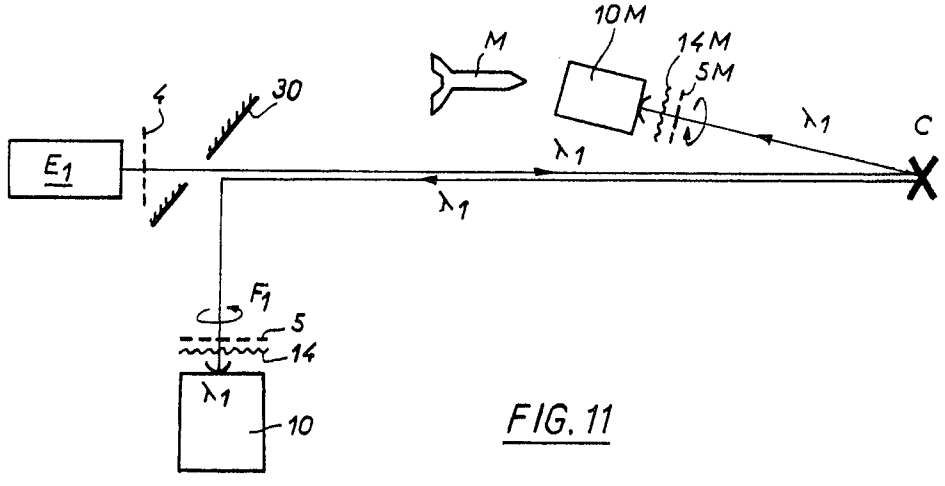

10M
M
14M
5M
4
30
λ1
C
E1
λ1
λ1
F1
5
14
λ1
10

FIG. 11

METHOD AND APPARATUS FOR MODULATING A PYROTECHNIC TRACER

It is well-known that the optical guidance of spinning missiles equipped with a radiation emitting source is made difficult by the fact that the ratio of the signal emitted by the radiating source to the background noise or clutter is often far from being a comfortable one.

This invention has for its object a method and apparatus which, with the aim of very substantially improving this signal/background noise ratio, allows modulating only the radiation emitted by the emitter source by taking advantage of the missile's spin.

The invention applies with particular advantage to modulating the radiation emitted by a pyrotechnic source of the tracer type that emits neither gases nor particles and is mounted on spinning missiles guided along an optical beam.

The method according to the present invention is characterized by the fact that it consists in the steps of mounting the radiation emitting source at the rear of the missile so that the radiation is emitted substantially along the spin axis of the missile as it follows its trajectory, filtering the radiation emitted by the emitter source by means of a polarizing filter angularly rigid with the missile, and placing a second polarizing filter in the optical path of the conventional ground-based receiver device, the effect of which second filter is to pick up the circularly polarized radiation emitted by the first filter and to cause it to be modulated sinusoidally at a frequency dependent on the relative rotation speed between the two filters, whereby the ratio of the modulated signal emitted by the emitter source to the unmodulated background noise is considerably increased and permits ready processing of the signal transmitted to allow optical command guidance of the missile.

The apparatus according to the invention for carrying the above method into practice is characterized in that it includes: a radiation emitting source placed at the rear of the missile, substantially on its spin axis; a first polarizing filter angularly rigid with the missile and positioned in front of the emitter source whereby to polarize its radiation; a heat-shield-forming transparent support for the polarizing filter; a second polarizing filter placed on the ground in the optical path of a conventional receiver device, the effect of which is to pick up the circularly polarized radiation emitted by the first filter and to cause it to be modulated, whereby the ratio of the modulated signal emitted by the emitter source to the unmodulated background noise is substantially improved and allows ready processing of the transmitted signal to permit optical guidance of the missile.

The present invention provides a particularly simple and effective way of overcoming the problems which become so complex with currently known means, namely:

optically guiding a missile along its ideal trajectory towards the target, especially in cases where the latter is itself illuminated by an optical beam;

discriminating between a missile and a target that is illuminated from the ground by an optical beam emitted by an auxiliary source in a region of the spectrum which is very close to or possibly identical with that of the beam from the emitter on board the missile;

command guiding a missile optically towards a target in cases where the missile and the target are both illuminated by the same optical beam;

and increasing the possible range and the accuracy with which a missile is guided towards a target, especially during the terminal part of the trajectory.

Further particularities and advantages of the present invention will become clearly apparent from the description which follows of different possible embodiments of the invention, given with reference to the accompanying non-limitative exemplary drawings.

In the drawings:

FIGS. **1** and **2** are explanatory diagrams of the design theory and operation of a modulation system according to the invention;

FIG. **3** is an explanatory diagram showing how the modulation frequency delivered by said system can be increased;

FIGS. **4** and **5** are explanatory diagrams showing how it is possible to automatically determine the angular position, in the field of reception, of a missile equipped with a modulation system according to the invention;

FIG. **6** is an explanatory diagram illustrating application of the invention to the optical command guidance of a missile;

FIGS. **7** and **8** are two block diagrams showing the basic principle of operation of a system for guiding a missile equipped with a modulation system according to the invention, for cases in which use is made of a direction-finder employing mechanical analysis and a direction-finder employing mosaic cells and electronic analysis, respectively;

FIG. **9** is an explanatory diagram showing application of the invention to the optical command guidance of a missile against a target illuminated by an optical beam;

FIG. **10** is an explanatory diagram showing application of the invention to the tracking of a target and a missile illuminated by the same optical beam; and

FIG. **11** is an explanatory diagram showing application of the invention to the automatic homing of a missile onto a target illuminated by an optical beam.

Before proceeding to describe the means for carrying the invention into practice, it should be recalled first of all that the invention has as its object to modulate the radiation emitted more particularly by a pyrotechnic source of the tracer type emitting neither gases nor particles and designed for mounting on spinning missiles guided along an optical beam.

The purpose of such modulation is to improve the signal/background noise ratio by making it possible to reduce the useful intensity radiated by the emitter source, and this without any risk of modifying its radiation pattern.

This is accomplished in a particularly simple and effective way by the subject system of this invention which it is now proposed to describe.

Reference is first had to the diagram in FIG. **1**, in which reference numeral **1** designates a pyrotechnic tracer of any convenient known type that emits neither gases nor particles (hereinafter referred to as an N.G.E. tracer), to the rear face of which is fixed a plate **2**, made of tantalum, for instance, which emits a radiation R_1. At a distance of a few millimeters from plate **2** is fixed a thermal protection plate **3**, preferably made of

Irtran 5 glass with MgO or of corrundum Al_2O_3 a few millimeters thick.

Applied against plate 3 is a polarizing filter 4, preferably made of acrylic plastics, the effect of which is to polarize the radiation R_1 and to consequently emit a polarized radiation R_2. It is to be noted that recourse is had to a polarizing filter capable of operating in the visible, infrared or ultraviolet regions of the spectrum with ranges of $\lambda = 0.4$ to 0.7μ, $\lambda = 0.7$ to 2.3μ and $\lambda = 0.25$ to 0.45μ respectively.

The above-described unit, generally designated as E_1, constitutes the emitter element of the modulation system according to this invention and is accordingly mounted at the rear end of a spinning missile guided along an optical beam.

The receiver element is formed by a second polarizing filter 5 which may be placed on the ground, without special precautions, in the optical path of the radiation R_2.

A reading of FIG. 1 will make it clear that the rotation of at least one of the two filters, in this instance the filter 4 which rotates (in the direction of arrow F) together with the missile to which it is fixed, will cause two gradual occlusions of radiating source R_2 at each angular rotation of 180°. The effect of this is to produce a sinusoidal modulation the frequency of which depends on the rotation speed of the filter.

More specifically, reference to FIG. 2 shows that if the angles of rotation of the filter 4 are represented along the X-axis and the value A of the radiated intensity along the Y-axis, then a 360° rotation of filter 4 will result in:

transmission of the radiated intensity at 0° and 180°, at which coincidence of the polarities of filters 4 and 5 permits such transmission,

and near total occlusion (depending on the filter characteristics) at 90° and 270°.

In other words, it emerges that the radiation which is emitted and received is modulated at twice the rotation frequency of the missile on which the emitter unit E_1 is mounted.

Further, it is important to note that since the waveform is sinusoidal, it is possible, as will be seen in greater detail hereinafter, to devise a selective narrowband amplifier centered upon twice the rotation frequency of the missile. The effect of this is not only to reduce electronic noise but also to suppress background noise almost entirely.

The latter produces a fluctuating continuous residual signal, as a result of which the emitter source, which is modulated, is separated from the noise signal and its information can be processed electronically in very simple fashion.

For instance, in the case of a missile spinning at between 10 and 20 revolutions per second and equipped with an N.G.E. tracer that is associated to a radiation polarizing system according to the invention, it is possible to obtain a modulation frequency of from 20 to 40 Hz.

It is very easy to devise a reception-selective electrical filter for such frequencies, as it is also to device the electronic amplification chain for processing the signals, two possible embodiments of which will be described hereinafter.

The modulation frequency can in fact be artifically increased upon reception by a few hundred cycles per second by causing the reception analysing filter 5 (see FIG. 3) to be rotated by an appropriate drive motor (not shown).

Reference to FIG. 3 shows that the background P, as seen only through analysing filter 5 by means of the objective glass 6 which gives an optical field of view of aperture Ω, is not modulated. Only the pyrotechnic emitter source equipped with polarizing filter 4, which is viewed with an angular aperture ω, is modulated by analysing filter 5, the rotation speed F_2 of which produces a much higher frequency than that originally produced by the rotation (spin) F_1 of the missile alone.

The signal/background noise ratio is therefore unquestionably improved.

The subject system of this invention further allows of determining very simply the position, at any precise instant, of the missile equipped with it in the field of reception.

To this end, as shown in FIG. 4 and 5, the analysing filter consists in this case of four sectors 5_A, 5_B, 5_C and 5_D of different polarities, the successive polarities being mutually spaced by 90° for example.

Each of these sectors will therefore have a phase which is different from those of the other sectors. These phases S_A, S_B, S_C and S_D are themselves mutually shifted by 90°, as shown in FIG. 5.

It will readily be appreciated that the position of the missile in the field of reception, at any precise instant, will be indicated by the polarity of the sector in which the missile's emitter source is seen.

From the practical standpoint, furthermore, it will be appreciated that the phase difference between the four sectors can then be applied to a phase comparator that delivers a voltage corresponding to the position of the missile's emitter source in the field.

The description which follows with reference to FIG. 6 to 8 is of an application of the invention for devising an optical missile command guidance system.

Referring first to FIG. 6 which schematically illustrates the principle of such an application, there is shown thereon a missile 7 rotating about its spin axis as it follows its trajectory In accordance with this invention, this missile carries at its rear end a pyrotechnic emitter source 1 in front of which is fixed a polarizing filter 4 in the manner described in detail with reference to FIG. 1. Further, the missile is equipped in the conventional way with a command guidance receiver 8 which controls means 9 for actuating the flight control surfaces. The missile moves through the optical field of aperture Ω of a conventional detecting and localizing direction-finder unit 10. In accordance with this invention, there is placed in the optical path of the reception unit 10 an analyzing filter 5 which, as described precedingly, may be either stationary or rotating.

As explained precedingly, the filter 5 picks up the polarized radiation R_2 emitted by emitter source 1, through the filter 4 and the module, at twice the rotation frequency of the missile if filter 5 is stationary or at a much higher frequency if it is itself rotated.

The signal delivered by detecting and localizing direction-finder 10 is processed in a corrective network 11 of any known convenient type and thereafter applied to a directional error measuring system 12 which in turn delivers two directional error voltages V_x and V_y proportional to the deviation of the missile from its ideal trajectory. These voltages V_x and V_y are sent by microwave link or conductor wires to the command

guidance receiver **8** controlling the control surface actuating means **9.**

The onboard transmitter unit E_1 cooperates with the ground receiver unit E_2 to permit command guidance of missile **7** along its ideal trajectory.

Reference is next had to the diagram in FIG. **7** for a description of a possible embodiment of a guidance system utilizing a mechanical analysis-type direction-finder, involving application of a modulation device to an N.G.E. pyrotechnic tracer, in accordance with the invention.

The onboard emitting unit E_1 is identical to the one described hereinabove and will now therefore be described further. Consequently the same reference designations as those in FIG. **1** will be repeated within the block $E_1$of FIG. **7.**

The ground receiving unit E_2 basically includes: an optical objective **6** placed in the optical field of aperture Ω in order to receive the polarized radiation R_2 from emitter source **1** and the module, through the agency of analyzing filter **5** which is preferably rotated in the direction F_2 ; an interference filter **13** of 1.7 μ wavelength and a conventional localization modulator disc **14.** The latter is rotated whereby to deliver a synchronous reference signal which subsequent to amplification by an amplifier **15** is applied to a phase comparator **16** as a phase S_1.

The frequency signal of the modulated radiation is picked up at **17** downstream of disc **14,** applied to a preamplifier **18,** filtered by a selective filter **19** and thereafter amplified at **20.** Obviously, the gain *g* of amplifier **20** is controlled by a distance corrector **21.** As shown schematically in the block **21** of FIg. **7,** the gain *g* must increase time-wise with increasing distance D.

The frequency signal delivered by amplifier **20** is applied to a conventional processing network **22** and thereafter to a phase comparator **16** as a phase S_2.

Phase comparator **16** then delivers directional error voltages V_x and V_y which, as stated precedingly, are sent by microwave link or conductor wires to the onboard command guidance system **8.**

In this form of embodiment of the mechanical-analysis direction-finder, the phase of signal S_2 in relation to the reference signal S_1 synchronous with the rotation of disc **14** indicates, at any particular moment in time, the polar angle of the position of the pyrotechnic source in the optical field of aperture Ω.

Reference is now had to FIG. **8** for an alternative possible embodiment in which guidance is assured by a direction-finder of the mosaic and electronic analysis type.

In this embodiment, the rotating modulator disc of the previously described embodiment is replaced by a direction-finder employing lead sulphide mosaic cells as schematized at **23.** An electronic switch **24** permits both vertical analysis at **25** and horizontal analysis at **26.** The signals issuing from these two analyses are applied to a sync mixer **27.** The signal delivered by this sync mixer, which delivers the reference signal, is applied to a video-sync mixer **28** which also receives the signal delivered by the amplifier **20** subsequent to processing (as in the previously described embodiment) by a preamplifier **18,** a selective filter **19** and a distance corrector **21.**

The signals emitted by the video-snyc mixer are applied to a comparator **29** which delivers signals indicating the position of the missile in the field in the vertical sense V and the horizontal sense H. As in the previous embodiment, the directional error voltages V_x and V_y are sent by microwave link or conductor wires to the onboard command guidance system **8.**

It will be manifest from the above description that the modulation system according to this invention offers numerous advantages over prior art systems.

Among these advantages, the following are outstanding:

the system is fully static;

it uses no mechanical or electrical modulating means;

it takes advantage of the missile's spin;

it requires no source of electric power for its operation;

it is simple, cheap, light in weight, compact and robust;

it provides effective protection against background noise;

it allows reducing the useful power radiated by the emitter source by comparison with a continuously radiating source.

With regard more particularly to the reason for selection of the utilization characteristic of a pyrotechnic source as the source emitting the radiation to be modulated, rather than the characteristic of a tungsten filament lamp or a lamp employing a gas such as xenon, mercury vapour, caesium or the like, this is fully justified by the fact that the power needed, the weight of several kilograms, the volume of several tens of cubic centimetres and, above all, the very low efficiency of approximately 1.5 percent in the spectral range utilized ($\lambda = 2.2\ \mu \pm 0.2$) of the latter-mentioned emitter sources is incompatible and not viable economically in the case of the expendable missile which must cost as little as possible.

For instance, in order to obtain a radiated intensity of 30 W/st/μ in the spectral region of $80 = 2.2 \pm 0.2$ it would be necessary to use a lamp requiring an electric power input of 2 kW, whereas whereas a pyrotechnic tracer of about 200 cm^3 is amply sufficient.

Similarly, an infrared power of 150 W/st/μ would require an electric power input of 10 kW whereas about 350 grams of pyrotechnic tracer would be adequate, and this without any intermediate power input.

Considering now the particular case of the embodiment described in FIG. **1,** the power P_R received at 2,000 metres from a pyrotechnic tracer equipped with a polarizing filter is given by the formula: $P_R = I_E \cdot T_W \cdot T_P \cdot T_f \cdot T_{Fi}/d^2$

where:

I_E is the intensity emitted along the axis, i.e. in this case 100/W/st/μ;

T_W is the atmospheric transmission factor at a distance of 2,000 metres under unfavourable conditions, in this case 0.6;

T_P is the transmission factor of the polarizing filter, in this case 0.4 for $\lambda = 2.2\mu$;

T_f is the transmission factor of the filter supporting window, in this case 0.95 for $\lambda = 1.7\ \mu$;

T_{fi} is the transmission factor of the interference filter, i.e. in this case 0.7 for $\lambda = 1.7\ \mu$, corresponding to the maximum intensity radiated by an N.G.E. type pyrotechnic tracer; and

d is the detection and guidance range, i.e. in this case **2,000** metres.

In this example, the formula gives:

$P_R = 1.10^2 \times 6.10^{-1} \times 4.10^{-1} \times (9.5 \times 10^{-1}) \times 7.10^{-1} / 4.10^{10}$

$= 4.10^{-10}$ W/cm$^2 \cdot \mu$

The useful power required for guidance is given by the formula: $P_u = P_{bi} \cdot K.F$

where:

P_{bi} is the internal noise ◫ 5.10^{-11} W/cm$^2 \cdot \mu$;

K is the signal/noise ratio (taken at a comfortable value of 4); and

F is the background noise factor, in this case equal to 1 (the residual of the polarizing filter being $\cong 5.10^{-3}\%$).

In this case $P_u = 5.10^{-11} \times 4 \times 1 = 2.10^{116\ 10}$ W/cm$^2 \cdot \mu$

It will be seen therefore that the subject system of this invention allows of obtaining a comfortable useful signal at a distance of 2 km even under unfavourable weather conditions.

In very sunny weather the signal delivered by the system according to this invention is stronger than the one delivered by an unmodulated system. Thus, for an atmospheric transmission factor at 2,000 m of $T_W = 0.8$, the power received is

$$P_R = 5.32 \times 10^{-10} \text{ W/cm}^2 \cdot \mu$$

It has been shown above how it is possible to provide an optical missile guidance system by means of two directional error voltages V_x and V_y proportional to the deviation of the missile from its ideal flight path, these voltages being delivered by a ground-based system and sent by microwave link or conductor wires to the onboard command guidance receiver 8 which controls the control surface actuator means 9 in order to direct the missile at its target.

Reference is next had to FIG. 9 for a description of an application of the invention for guiding a missile against its target in the case where the latter is itself illuminated by an optical beam.

Schematically represented on FIG. 9 is the background P seen through the ground-based analysing filter 5, in which lie, at a given moment in time t, the target C which follows its own path and the missile M which is to be command guided so that it reaches the target C at an instant in time $t + \epsilon$.

In this particular example, the target C is illuminated by an optical beam of aperture Ω, such as an infrared laser beam emitted by an appropriate emitter E in the spectral range λ_1. In this instance, should the missile M be equipped as described in detail precedingly with an infrared emitter E_1 operating in a spectral range λ_2 very near to or identical with the spectral range λ_1 of optical emitter E then the problem of discriminating between missile M and target C arises.

This problem may be overcome in a particularly simple and effective way by means of the improvement according to this invention, to be described hereinbelow.

Firstly, the angular position of missile M is detected by the method described in detail precedingly, that is to say that the beam emitted in the spectral range λ_2 by the emitter E_1 on board the missile is filtered by the first polarizer 4 rotating with the missile and then directed, through the agency of a mirror 30 for example, at a conventional ground-based direction-finding receiver 10_M through a second polarizing filter 5.

Secondly, the target C is localized by a second likewise ground-based direction-finding receiver 10_C that receives the laser beam which is emitted by emitter E in the spectral range λ_1, reflected by target C and mirror 30, separated from the beam emitted by emitter E_1 by means of a dichroic screen 31 that intercepts the two merging beams reflected by mirror 30, and thereafter directed at the receiver 10_C, for instance through the agency of a further mirror 32.

The target and the missile are differentiated through the use on receiver 10_M of a modulation frequency F_1 which as described precedingly is produced by the circular polarization of the beam passing through dichroic screen 31 and intercepted by receiver 10_M through the rotating polarizing filter 5 and the missile position-detecting modulator 14_M.

Manifestly, receiver 10_C is likewise provided with a target position detecting modulator 14_C.

It will be clearly apparent that this improved method will cause the target to appear either as a continuous signal or as a modulated signal different from the missile signal, and consequently that clear discrimination between the target and the missile will be achieved.

In an alternative embodiment, it would be possible to modulate the laser emitter beam E at a frequency F_2 other than F_1 by applying the same method. In both cases the signals emitted by receivers 10_M and 10_C are applied to a data mixer and processing network 11 which feeds a directional error system 12 which in turn delivers the two directional error voltages V_x and V_y proportional to the deviation of the missile from its ideal trajectory. These voltages V_x and V_y are sent by microwave link or conductor wires to the command guidance receiver which controls the actuator means of the missile's control surfaces, as described in detail hereinabove.

Thus the emitter unit E_1 on board the missile M, the laser emitter E illuminating the target C, and the ground-based receiver unit E_2 jointly allow of guiding the missile M against the target C illuminated by an optical beam.

It should be noted that the exhaust nozzle of the missile's propulsion unit radiates a certain amount of energy which will be more or less attenuated depending on the wavelength and spectral band used for transmission and reception.

It should be noted that although a continuous residual signal will be produced, the latter will be merged with the modulated signal from the emitter E_1 fixed to the missile. Hence there will be no troublesome effects since this residual signal will follow in strictly identical fashion the motions of the onboard emitter source.

Reference is now had to FIG. 10 for a description of an application of this improved method to the localizing of a target C and a missile M illuminated by the same optical beam.

Since the problem to be overcome here is to detect the angular position ϵ of the missile flight vector in relation to the position of the target C, it is possible to proceed as follows:

Emitter source E_1, which is normally fixed to the rear of the missile, is in this case placed on the ground so that its optical beam in the spectral range λ_1 illuminates both the missile and the target.

Further, the rear of the missile is equipped with a tetrahedral rear reflector 33 and with the polarizing filter 4, while the direction-finding receiver 10 equipped

with the rotated second polarizing filter **5** and the localizing modulator disc **14** is placed on the ground as in the previous example described with reference to FIG. **9.**

It will be immediately manifest from FIG. **10** that the angular position **68** of missile M is detected by the backward reflection of the optical beam emitted, the latter being then reflected by mirror **30** for interception by rotating polarizer **5** positioned before direction-finding receiver **10.**

The target C is localized by the same direction-finding receiver **10,** which receives the non-polarized beam reflected by the target.

As already explained, discrimination between the target and the missile is effected by utilizing a frequency F_1 generated by the circular polarization of the beam reflected by the tethrahedral rear reflector **33** which, as already stated, is equipped with the polarizer **4** mounted on board the missile M.

It will be clear from the foregoing that:

1. the target C will appear in the form either of a continuous signal or of a signal of frequency F_2 if the emitter beam is pulse-modulated at M_1, as shown in dash lines in FIG. **10**;

2. the missile M will appear in the form of an amplitude-modulated signal of frequency F_1 that will be differentiated from the signal issuing from the target C.

This being so, there will be very clear discrimination between missile M and target C, which would be very difficult to accomplish if the method according to this invention were not applied.

As in the previous embodiment, the signals emitted by direction-finding receiver **10** are applied, after elimination of background clutter in an appropriate network **34,** to a data mixing and processing network **11** which comprises a comparator for delivering signals indicating the positions of the missile and the target in the optical field in the vertical and horizontal senses. Network **11** energizes a directional error system **12** which in turn delivers two directional error voltages V_x and V_y proportional to the deviation of the missile from its ideal trajectory. These voltages V_x and V_y are sent by microwave link or conductor wires to the onboard command guidance receiver controlling the means for actuating the missile's control surfaces, as described in detail precedingly.

The method of localizing a target and a missile illuminated by the same optical beam, described above with reference to FIG. **10,** can be supplemented with advantage in such manner as to allow semi-active terminal homing of the missile in order to increase both the feasible range and the accuracy of the launch.

FIG. **11** schematically illustrates the manner in which the missile M may be homed onto the target C, itself illuminated by an optical beam, more particularly during the terminal part of the trajectory.

In this particular application of the improved method according to the invention, the position of the emitter and receiver units are reversed, that is to say that the emitter unit E_1 and its polarizing filter **4** are ground-based, whereas the direction-finding receiver unit 10_M with its analysing filter 5_M and its modulator 14_M is mounted on board the missile.

The polarized beam is furthermore used to detect the target C by illuminating it and using its coefficient of reflection (which varies with the wavelength used and the target structure) in order to intercept the beam reflected by the target by means of a ground-based direction-finding receiver **10** which naturally includes a rotated analysing filter **5** and a modulator **14.**

Further, the polarised beam emitted by source E_1 and reflected by target C is likewise detected by the receiver 10_M positioned in the nose of missile M. This onboard homing receiver determines angular deviations from the target in the manner well-known per se. If performs the onboard corrections by generating the commands required to ensure that the missile continues along the ideal flight path towards the target.

As stated precedingly, the initial part of the missile flight path can be controlled by guidance means utilizing the method described with reference to FIG. **10,** for example. This solution is particularly simple since all that is necessary is to equip the rear of the missile with a tetrahedral backward receiver and a polarizing filter, this equipment being used at the start of the trajectory while the direction-finding receiver unit positioned in the nose of the missile is used during the terminal part of the trajectory, thereby increasing the range and improving the accuracy of the missile.

It goes without saying that changes and substitutions of parts may be made in the preferred exemplary embodiments herein described, without departing from the scope of the invention as set forth in the appended claims.

I claim:

1. A method of modulating the radiation emitted by a pyrotechnic source of a tracer type mounted on a spinning missile guided along an optical path by means of a ground-based receiver device, in order to improve the transmitted-signal/background noise ratio, consisting in the steps of: placing said radiation emitter source at the rear of the missile so that said radiation be emitted substantially along the spin axis of the missile as the same follows its trajectory; filtering said radiation emitted by said emitter source by means of a polarizing filter rotating with the missile; and placing, in the optical path of said ground-based receiver device, a second polarizing filter the effect of which is to pick up the circularly polarized radiation emitted by said first filter and cause it to be sinusoidally modulated at a frequency dependent on the resultant relative rotation speed between the two filters, whereby the ratio of the modulated signal emitted by the emitter source to the unmodulated said background noise is considerably increased and permits ready processing of the transmitted signal to allow optical command guidance of the missile.

2. A method as claimed in claim **1,** wherein the ground-based second polarizing filter is rotated in order to increase the modulation frequency of the signal.

3. A method as claimed in claim **2,** wherein, in order to permit furthermore determining at any given instant the position of the missile in the optical field of reception, the ground-based second polarizing filter is formed of a plurality of sectors of different polarities each delivering a determinate modulated signal out of phase with respect to the others and defining the sector in which the emitter source is viewed and hence the position of the missile in the optical field of reception.

4. A method as claimed in claim **1,** wherein, in order to permit optical command guidance of the missile toward a target itself illuminated from the ground by an optical beam emitted by an auxiliary source in a spec-

tral region very close to that of the beam from the emitter on board the missile, said method further consists in directing said polarized radiation emitted by the missile, on the one hand, and the radiation emitted from the ground and reflected by the target, on the other, at a common ground-based dichroic screen which on the one hand transmits the radiation emitted by the missile to a ground-based direction-finding receiver comprising the analysing filter and on the other reflects the radiation reflected by the target toward a second ground-based receiver, whereby the ratio of the modulated signal emitted by the emitter source on board the missile to the unmodulated signal emitted by the ground-based auxiliary source and refleceted by the target is considerably increased and permits ready processing of the two signals to allow optical command guidance of the missile toward the target.

5. A method as claimed in claim 4, wherein the radiation emitted by the ground-based auxiliary emitter source is filtered by a polarizing filter and the same radiation is intercepted subsequent to reflection off the target and the dichroic screen by a polarizing filter positioned before the reception optics of the second ground-based receiver, at least one of the two said filters being rotated whereby to cause the signal emitted by the auxiliary source to be likewise modulated but at a frequency differing greatly from that of the signal transmitted by the emitter source on board the missile.

6. A method of modulating the radiation emitted by a pyrotechnic source of the tracer type mounted on a spinning missile guided along an optical path by means of a ground-based receiver device, in order to improve the transmitted-signal/background noise ratio, and in order to permit optical command guidance of the missile toward a target in cases where the missile and the target are both illuminated by the same optical beam, comprising the steps of: placing said radiation emitter source on the ground in order to illuminate both the missile and the target; filtering said radiation emitted by said emitter source by means of a polarizing filter on board and rotating with the missile; and placing, in the optical path of said ground-based receiver device, a second polarizing filter the effect of which is to pick up the circularly polarized radiation emitted by said first filter and cause it to be sinusoidally modulated at a frequency dependent on the resultant relative rotation speed between the two filters; and reflecting the radiation from said emitter source on the one hand, by a backward reflector at the rear of the missile before being polarized by the polarizing filter on board the missile and, on the other, by the target itself, the two radiations so reflected being picked up directly by a single ground-based direction-finding receiver comprising the analysing filter, whereby the ratio of the modulated signal from the missile to the unmodulated signal from the target is considerably increased and permits ready processing of the two signals to allow optical command guidance of the missile toward the target.

7. A method as claimed in claim 6, wherein the single ground-based emitter source emits a pulse-modulated beam, the two signals picked up by the ground-based receiver being thereby modulated at very different frequencies enabling them to be clearly differentiated.

8. A method as claimed in claim 6, wherein, in order to increase the possible range and accuracy of guidance of the missile toward the target, more particularly during the terminal part of the trajectory, the radiation emitted by the single ground-based emitter source is polarized by a polarizing filter and reflected by the target whereby to be picked up, on the one hand, by a ground-based receiver comprising a rotated analysing filter delivering a modulated target-detection signal and, on the other, by a homing receiver placed in the nose of the missile that processes the signal corresponding to the radiation reflected by the target thereby to allow optical homing of the missile onto the target.

9. A system for modulating the radiation emitted by a pyrotechnic source of the tracer type, adapted to be mounted on spinning missiles guided along an optical beam by means of a ground-based receiver device, in order to improve the transmitted-signal/background-noise ratio, comprising:

a radiation emitter source placed at the rear of the missile substantially along the spin axis thereof;

a first polarizing filter rotating with the missile and positioned before said emitter source whereby to polarize the radiation therefrom;

a heat shield forming transparent support for supporting said first polarizing filter;

a second polarizing filter placed in the optical path of said ground-based receiver device and adapted to pick up and modulate the circulary polarized radiation emitted by said first filter;

whereby the ratio of the modulated signal emitted by said emitter source to the unmodulated said background noise is considerably improved and permits ready processing of the transmitted signal to allow optical guidance of the missile.

10. A system as claimed in claim 9, wherein means are further provided for rotating said ground-based second polarizing filter and thereby increasing the signal modulation frequency.

11. A system as claimed in claim 9, wherein said ground-based second polarizing filter is formed of a plurality of sectors of different polarities each of which delivers a determinate modulated signal out of phase with respect to the others and defining the sector in which the emitter source is viewed and hence the position of the missile in the optical reception field.

12. A system as claimed in claim 9, wherein, in order to permit optical command guidance of the missile toward a target, it further includes: a ground-based auxilliary emitter source emitting a target-illuminating radiation in a spectral region very close to that of the beam from the emitter on board the missile; and a ground-based dichroic screen which simultaneously receives, on the one hand, the polarized radiation emitted by the onboard emitter which said screen transmits toward the ground-based direction-finding receiver comprising the analysing filter and, on the other, the radiation emitted by the auxiliary emitter source and reflected by the target, which said screen reflects toward a second ground-based receiver, whereby the ratio of the modulated signal emitted by the emitter source aboard the missile to the unmodulated signal emitted by the ground-based auxiliary source and reflected by the target is considerably increased and permits ready processing of the two signals to allow optical command guidance of the missile toward the target.

13. A system as claimed in claim 12, wherein the ground-based auxiliary emitter source is equiped with

a polarizing filter and a second ground-based receiver with an analysing filter, at least one of the two filters being rotated in order that the signal emitted by the auxiliary source be modulated at a frequency differing greatly from that of the signal transmitted by the emitter source aboard the missile.

14. A system for modulating the radiation emitted by a pyrotechnic source of the tracer type adapted to be mounted on spinning missiles guided along an optical beam by means of a ground-based receiver device, in order to improve the transmitted-signal/background-noise ratio, and in order to permit optical command guidance of the missile toward a target in cases where the missile and target are both illuminated by the same optical beam, comprising:

a radiation emitter source placed on the ground so that it illuminates both the missile and the target;

a first polarizing filter on board and rotating with the missile;

a backward reflector positioned at the rear of the missile in order to reflect the radiation emitted by said ground-based emitter source through said first polarizing filter;

a ground-based direction-finding receiver having a second polarizing filter placed in the optical path of said receiver and adapted to simultaneously pick up and modulate the circulary polarized radiation emitted by said first filter and the radiation reflected by the target

whereby the ratio of the modulated signal from the missile to the unmodulated signal from the target is considerably increased and permits ready processing of the two signals to allow optical command guidance of the missile toward the target.

15. A system as claimed in claim **14,** wherein said ground-based emitter source is pulse-modulated in order that the two signals picked up by said ground-based receiver device be modulated at greatly differing frequencies.

16. A system as claimed in claim **14,** wherein, in order to increase the possible range and accuracy of guidance of the missile toward the target, more specifically during the terminal part of the trajectory, it includes: a polarizing filter placed before the emitter source in order to polarize the radiation therefrom that illuminates and is reflected off the target; a ground-based receiver comprising a rotated analysing filter, said receiver picking up the radiation reflected by the target and delivering a modulated target detection signal; and a homing receiver positioned in the nose of the missile that processes the signal corresponding to the target-reflected radiation whereby to permit optical homing of the missile onto the target.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,796,396 Dated March 12, 1974

Inventor(s) Christian CROVELLA

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

On the cover sheet under Item [76] insert the following:

Assignee: SOCIETE NATIONALE INDUSTRIELLE AEROSPATIALE, Paris, France

Signed and sealed this 30th day of July 1974.

(SEAL)
Attest:

McCOY M. GIBSON, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

FORM PO-1050 (10-69)

USCOMM-DC 60376-P69
* U.S. GOVERNMENT PRINTING OFFICE : 1969 O—366-334.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,796,396 Dated March 12, 1974

Inventor(s) Christian CROVELLA

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

On the cover sheet under Item [76] insert the following:

Assignee: SOCIETE NATIONALE INDUSTRIELLE AEROSPATIALE, Paris, France

Signed and sealed this 30th day of July 1974.

(SEAL)
Attest:

McCOY M. GIBSON, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

FORM PO-1050 (10-69)

USCOMM-DC 60376-P69
* U.S. GOVERNMENT PRINTING OFFICE : 1969 O—366-334.