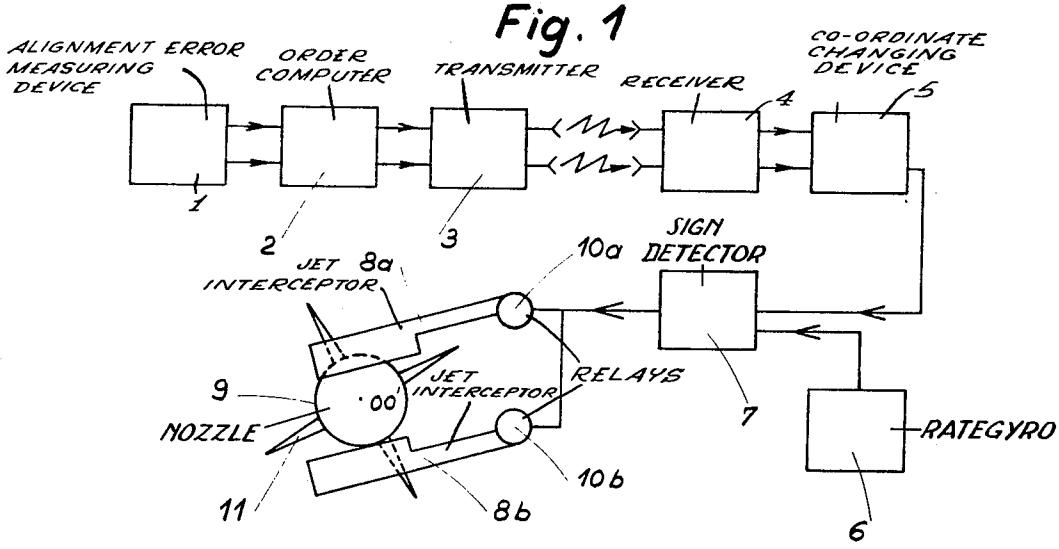
Dec. 26, 1967 G. STCHERBATCHEFF 3,360,214

LINE-OF-SIGHT GUIDANCE SYSTEM FOR MISSILES

Filed March 8, 1966 4 Sheets-Sheet 1

Fig. 1



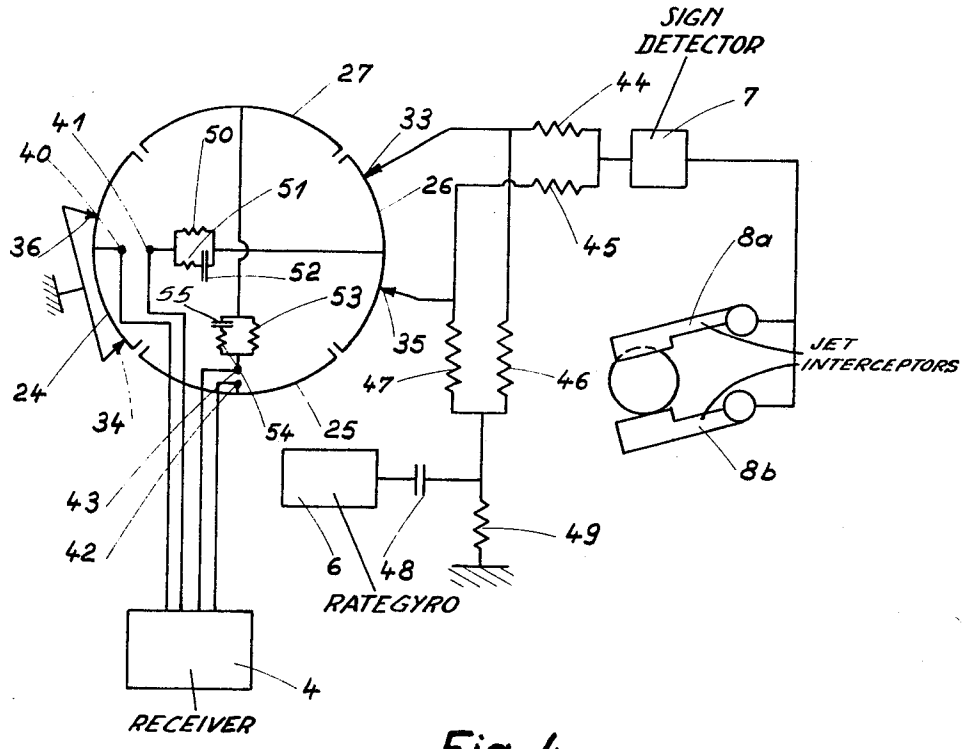


Fig. 4

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LINE-OF-SIGHT GUIDANCE SYSTEM FOR MISSILES

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Fig. 3

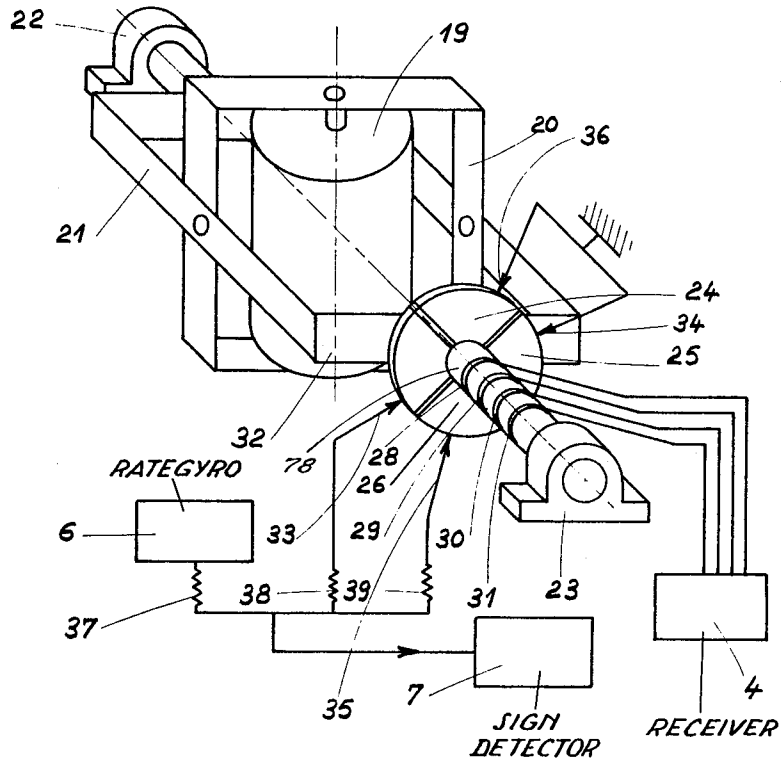
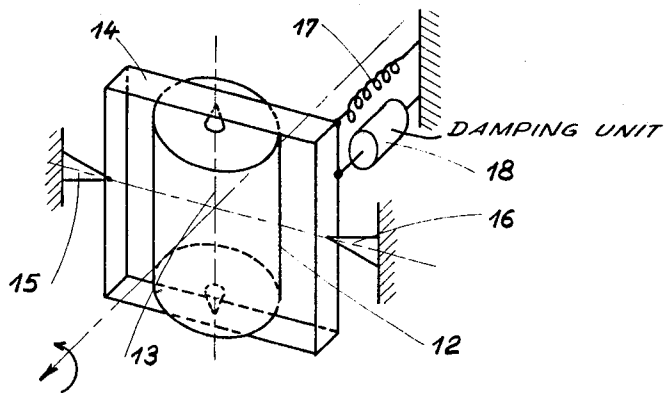


Fig. 2



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LINE-OF-SIGHT GUIDANCE SYSTEM FOR MISSILES

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Fig. 5

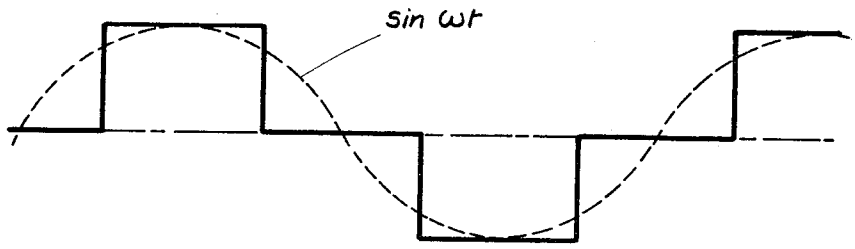


Fig. 6

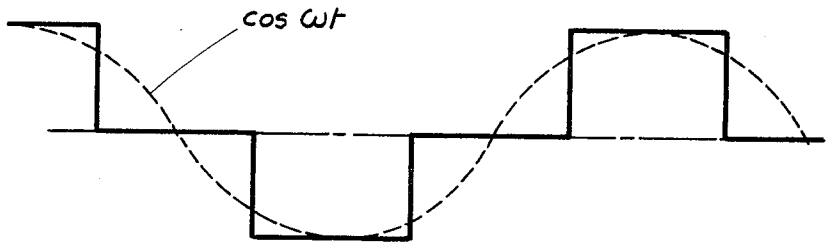
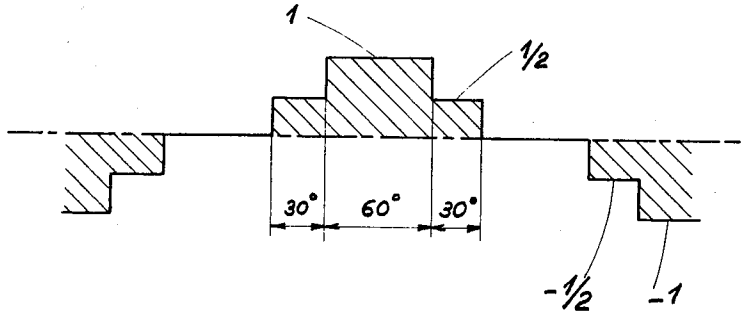


Fig. 7



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LINE-OF-SIGHT GUIDANCE SYSTEM FOR MISSILES

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Fig. 8

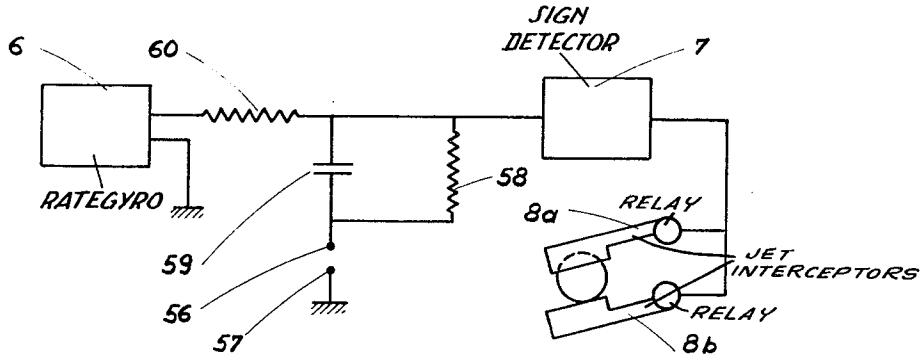
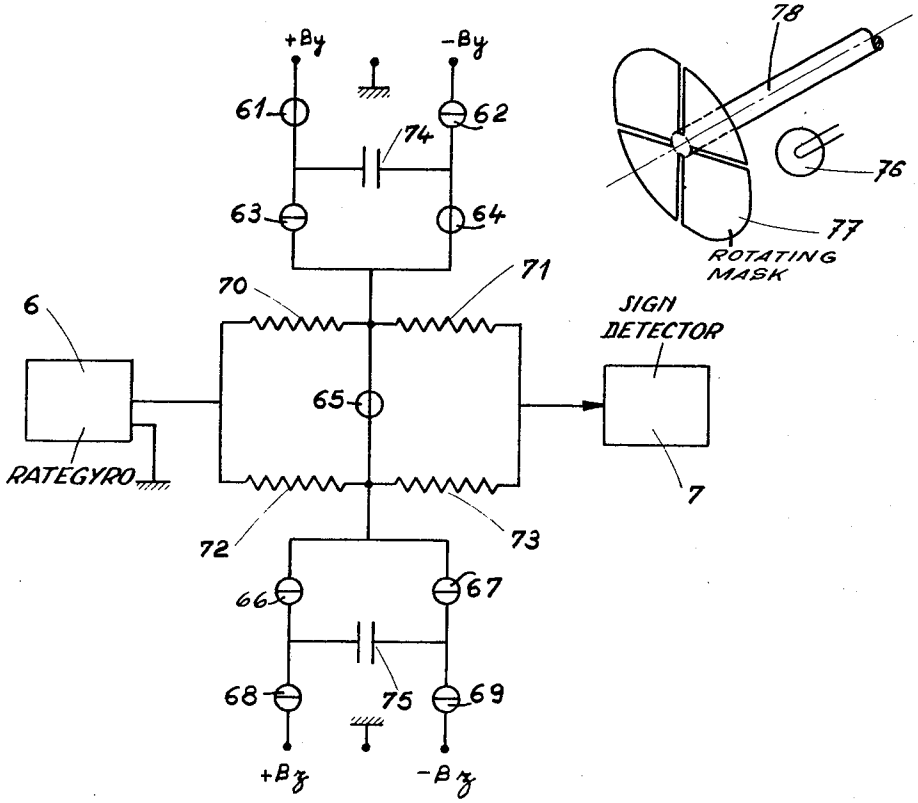


Fig. 9



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3,360,214

LINE-OF-SIGHT GUIDANCE SYSTEM FOR MISSILES

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Filed Mar. 8, 1966, Ser. No. 532,699
Claims priority, application France, Mar. 16, 1965, 9,361, Patent 1,458,137
6 Claims. (Cl. 244—3.14)

ABSTRACT OF THE DISCLOSURE

The invention broadly relates to the guiding of aircrafts. It provides a device for stabilizing the transverse trim of an autorotative missile as guided in alignment with the launching station-target axis, with a view further to increase the accuracy of guidance.

The present invention relates to a system for guiding aircraft and more especially jet-propelled autorotative missiles which spin in flight at a constant speed ω about their longitudinal axes of revolution (rolling axes).

The invention is more specifically directed to the stabilization of the transverse trim of an autorotative missile as guided in position with respect to the launching station-target axis or "line of sight."

It is known to control the flight of an autorotative missile by transmitting from the ground to the missile orders which produce action on flight-control members working in two planes at right angles, by determining from the ground any deviations from the line of sight and by correcting the orders which are transmitted to the flight-control members as a function of said deviations by means of a control loop.

It is an object of the invention to provide a method and device which enable one to guide an autorotative missile with increased accuracy of guidance and rapidity of response. The method according to the invention comprises the steps of measuring the rate of transverse trim of the missile and of correcting the order which is transmitted to the flight-control members according to the result of this measurement.

According to a feature of the invention, the said device includes a control chain consisting of a single measuring device and two flight-control members which supply one pitching-couple component, said control chain, which is driven in rotation by the missile, being intended to operate alternately in pitching motion and yawing motion and being capable of controlling the performance of movements both in direction and in depth.

According to another feature of the invention, the comparison of the order with the measurement of trim velocity with a view to obtaining a signal adapted for controlling the actuation of the flight-control members is effected in a device which will be termed hereinafter a "switched network" and which carries out at the same time the changing of co-ordinates which is necessary for the purpose of converting signals defined with respect to fixed references into signals which are defined with respect to missile-based references, and conversely.

The different features and advantages of the invention will become readily apparent from the description which now follows below, reference being made to the accompanying drawings, in which:

FIG. 1 is a block diagram of a guidance installation in accordance with the invention;

FIG. 2 represents a rate gyroscope which is designed to measure the transverse trim velocity;

FIG. 3 is a digram of a first embodiment of a switched network, alternative embodiment of which are shown in FIGS. 4 and 9;

FIGS. 5, 6 and 7 represent functions which are generated by the switched network and which constitute an approximation of the function which defines the change of co-ordinates; and

FIG. 8 represents a fictitious, non-switched network which is intended to provide a clearer understanding of the operation of the switched network.

The guidance apparatus which is shown in FIG. 1 comprises a device **1** which is capable of measuring the "alignment error," that is to say the difference between the actual position of the center of gravity of the missile and the position which this latter should theoretically have at each instant, taking into account the direction of the target.

A measuring device of this type is already known per se. For example, such a device comprises on the one hand a sighting telescope which a member of the ground crew directs as accurately as possible onto the target and, on the other hand, a missile-locating system. Said locating system in turn comprises a flight log consisting of an infra-red radiation source placed at the rear end of the missile and a goniometer, the optical axis of which is common with that of the sighting telescope and which supplies indications of the deviations between the missile and and said optical axis.

The device **1** is connected to an order computer **2** which, starting from the alignment error, produces a direction order By and a depth order Bz.

In the example which is considered above, the computer **2** will for instance comprise a first device for producing a first signal which is proportional to the deviation between the missile and the optical sighting line or axis and a second device for producing a second signal which is a function of the velocity of relative motion of said optical axis, and means for adding the first signal and second signal.

The order signal thus produced is transmitted to the missile receiver **4** by means of a transmitter **3**. On board the missile, a co-ordinate-changing device **5** converts the orders defined with respect to a ground-based system of co-ordinates into orders defined with respect to a missile-based system of co-ordinates.

The equipment carried by the missile additionally comprises a device **6** which takes a measurement of the instantaneous angular velocity of the missile about an axis at right angles to the rolling axis of the missile (measuring axis) and produces an electric signal which is proportional to said angular velocity.

The signals which are delivered from the devices **5** and **6** are applied simultaneously to a sign detector **7** which produces an electric signal having constant amplitude and either positive or negative polarity depending on the sign of the order to be transmitted to the flight-control system. Said signal is applied to a flight-control system which operates on the all-or-nothing principle and which is capable of applying to the missile constant pitch control torque in a positive or negative direction with respect to an axis at right angles to its rolling axis.

A flight-control system of this type is advantageously of the type described in French Patent No. 1,099,901 as filed on August 9, 1948, in the name of the French Government as represented by the Secretary of State for the Armed Forces (Air Force) in respect of: "Device for deflecting a high-velocity gas jet discharged from a nozzle." Accordingly, said flight-control system comprises two blades **8***a* and **8***b* which are movable from an "inactive" position in which they do not intercept the jet which is discharged from the nozzle **9** (as shown looking on the rear end) to an "active" position in which they

intercept the jet, respectively, at two diametrically opposite areas of the right cross-section of said nozzle. The motion of the blades **8***a* and **8***b* from the inactive to the active position is controlled by electromagnetic devices **10***a*, **10***b* which are actuated by the signal either in one direction or in the other depending on the sign of this latter.

The useful effect of the jet-control members is a component of thrust at right angles to the rolling axis as exerted in a radial plane or so-called "plane of action of the control members." By reason of the fact that the said plane of action rotates with respect to a fixed reference at the velocity of rotation ω of the missile about its rolling axis, any variation in flight of the missile can be produced or controlled in this manner.

The alignment guidance system which is represented schematically in FIG. 1 constitutes a feed-back loop which tends to reduce to zero any errors in alignment as a result of suitable action exerted on the flight-control system.

In an alignment guidance system of this type, the present invention is mainly directed to the trim-stabilizing unit or "stabilizer" which is more especially composed of the devices **5–6** and **7**.

In short, the purpose of said stabilizer is to reduce any deviation from the line of sight and to improve the precision of guidance and the speed of response to orders, this being obtained by taking into account at each instant the real angular velocity of the missile which is dependent, not only on the order received, but on a number of different disturbing effects. By virtue of the presence of the stabilizer (**5–6–7**), the order received no longer acts directly on the flight-control members but is compared with the measured angular velocity, and it is the result of this comparison which produces action on the flight-control system.

The stabilizer (**5–6–7**) performs the function of feed-back loop constituted as follows: the missile has at each instant a certain angular velocity about the measuring axis herein above defined; the device **6** measures said angular velocity and generates a signal which combines with the signal of the order subsequently received, and the detector **7** applies to the flight-control system a signal having a sign such that, in the absence of any order, the action of the flight-control system tends to reduce said angular velocity to zero. In fact, a so-called "limit cycle" is established within the loop and, when no order is transmitted, maintains at zero the mean value of said angular velocity and therefore of the measuring signal. In the presence of an order, it is the mean value of the sum of the measuring signal and of the order signal which is maintained at zero value.

It should be pointed out that the control system which is provided by the stabilizer must be capable of responding to the sum of the frequency of the order and of the frequency of rotation of the missile about its rolling axis. This sum must therefore be smaller than the frequency of self-oscillation of the feed-back system. The speed of response of the jet-control members makes it possible to obtain a high self-oscillation frequency and consequently a satisfactory response of the complete assembly.

A stabilizing device of this type can be produced at low cost and in a small size, with the result that it will prove particularly suitable for small missiles.

Furthermore, the said device is unaffected by aerodynamic asymmetry of the missile and by zero errors of the measuring device. In fact, any continuous disturbance results in a torque which is caused to rotate about the rolling axis and which consequently has a zero mean value.

Reference being made to FIG. 2, there will now be described one preferred embodiment of the device for measuring angular velocity. The following description, which is intended to permit a clearer understanding of the invention, is in fact concerned with a device of a general

type which is already known and which could be replaced by any other device of like design.

The device described hereunder is constituted by a rate gyroscope which is essentially made up of a rotor **12** which spins about an axis **13** forming one of the central axes of symmetry of a frame **14**. Said frame is rotatably mounted on two pivots **15–16** which are fixed to the missile along the other central axis of symmetry of the frame **14** which coincides with the rolling axis.

Any angular velocity of the missile about an axis at right angles to the plane of the frame **14** produces a torque which has a tendency to cause said frame to rotate about the pivots **15–16**. This rotation is opposed by a spring **17** and a damping device **18**. The torque is measured by the displacement of the frame **14**, which produces action on a transducer, not shown in the drawings, and said transducer in turn generates a signal which is proportional to the angular velocity to be measured.

Reference being made to FIG. 3, there will now be described one simple embodiment of the device **5** for changing co-ordinates which essentially forms part of the invention.

The device referred to comprises a gyroscope which essentially consists of a gyro rotor **19** which spins about one of the central axes of symmetry of an inner frame **20**. The frame **20** is rotatable about its second central axis of symmetry and is mounted on one of the central axes of symmetry of an outer frame **21**. Said outer frame is in turn mounted in two bearings **22** and **23** on a second central axis of symmetry which coincides with the rolling axis of the missile. A switch comprises four conductive sectors **24–25–26–27** which are insulated with respect to each other and an insulating shaft **78** fitted with four conductive rings **28–29–30** and **31**. The shaft **78** which is oriented along the rolling axis is integral with the side **32** of the frame **21**.

The receiver **4** applies potentials By, Bz, —By and —Bz respectively to the four sectors **24** to **27** via the rings **28** to **31**.

Two pairs of diametrically opposite brushes respectively designated by the reference numerals **33**, **34** on the one hand and **35**, **36** on the other hand are connected as follows: the brushes **34** and **36** are connected to ground whilst the brushes **33** and **35** are connected to the sign detector **7** as follows: three resistors **37**, **38** and **39** are connected in common at one of their extremities to said sign detector **7** whilst the other extremities of said resistors are respectively connected to the device **6** for measuring angular velocity, to the brush **33** and the brush **35**.

The gyroscope maintains the sectors **24** to **27** stationary with respect to the ground, whilst the brushes which are associated with the missile carry out a movement of rotation about the rolling axis at the speed ω and consequently sweep the conductive sectors.

The resistors **37–38–39** effect the summation of the gyrometric signal and a certain function of the signals which are respectively picked-up by the brushes **33** and **35**, that is to say, the signals $\pm By$ and $\pm Bz$. The brush pitch is determined so that said function should correspond to a sufficient approximation of the function which defines the change of co-ordinates from ground to missile.

The above-mentioned function is in fact as follows:

$$B = By \cos \omega t + Bz \sin \omega t$$

FIGS. 5 and 6 show that the functions sin ωt and cos ωt can be replaced with a sufficient approximation in certain cases by functions which assume during one cycle the necessary values 0, +1, 0 and —1. Such a result would be achieved with a single pair of brushes. In fact, the addition of a second pair of brushes and resistors supplying the mean value of their potentials makes it possible to provide a sequence of steps which results in a closer approximation of the function sin ωt or cos ωt; this sequence of steps is shown in FIG. 7, in which the angles indicated relate to the relative displacements of the brushes and the

numerals relate to the relative amplitudes of the steps which are respectively, during one cycle: +½ (through an angle of 30°); +1 (through 60°); +½ (through 30°); 0 (through 60°); —½ (through 30°); —1 (through 60°); —½ (through 30°); and 0 (through 60°).

It has been possible to demonstrate that the function shown in FIG. 7 does not contain a harmonic component 3, which is a satisfactory result.

In FIG. 4, there is shown a more elaborate embodiment of the trim-stabilizing device.

There are again shown in FIG. 4 the sign-detecting device **7**, the jet-intercepting members **8***a* and **8***b* and the device **6** for measuring the angular velocity of the missile (rate gyroscope).

The gyroscope which forms part of the co-ordinate-changing device and which is designed and arranged as explained earlier in reference to FIG. 3 is not again shown.

FIG. 4 simply shows in a diagrammatic manner the four conductive sectors **24–25–26–27** and the brushes **33–34–35–36** which have already been described.

The co-ordinate-changing device which is illustrated in FIG. 4 comprises a pair of terminals **40–41** which are respectively connected to the sectors **24** and **26** and between which is applied the order signal By and a pair of terminals **42–43** which are respectively connected to the sectors **25** and **27** and between which is applied the order signal Bz derived from the receiver **4**.

The brushes **34** and **36** are connected to ground whilst the brushes **33** and **35** are connected to the sign detector **7** through resistors **44** and **45** respectively.

The output of the rate gyroscope **6** is connected to the common point of two resistors **46** and **47** through a junction capacitor **48** decoupled by a resistor **49** which is connected to ground.

The resistor **46** is connected to the common point between the resistor **44** and the brush **33** whilst the resistor **47** is connected to the common point between the resistor **45** and the brush **35**.

A circuit composed of a resistor **50** which is connected in parallel with the assembly consisting of a resistor **51** and a series-connected capacitor **52** connects the terminal **41** to the sector **26**.

Similarly, a circuit composed of a resistor **53** which is connected in parallel with the assembly consisting of a resistor **54** and a series-connected capacitor **55** connects the terminal **43** to the sector **25**.

In the device of FIG. 3, the response to the orders B is governed by a law having the form:

$$B=K\theta'$$

wherein θ' is the angular velocity which is measured by the rate gyroscope.

In order to increase the speed of response and the precision of the stabilizer, it is endeavoured by means of the alternative form of FIG. 4 to establish a law having the form:

$$B+K1B'=K2\theta'$$

wherein B' is the derivative of the order with respect to time.

The above formula expresses the fact that the signal B which is introduced within the feed-back loop formed by the stabilizer contains a term which is proportional to the integral of the input θ' of said loop.

This method of introduction of an integral term in a feed-back system is well known per se. It is merely necessary in order to produce the integral term to introduce a resistor-capacitor circuit or so-called "imperfect integrator."

The application of this known method to the stabilizing device in accordance with the invention is in no sense self-evident by reason of the fact that the control input is constituted by a value θ' of the angular velocity of the missile as measured by reference to a single shaft which also rotates at the angular velocity ω as herein above defined.

In order that the integration of said angular velocity which is thus modulated, as it were, at the high frequency $\omega/2\pi$, should perform its intended function in the feed-back system, it is obviously necessary that said integration should be effected at an angular velocity which has been previously demodulated, that is to say, after a change of co-ordinates which restores thereto the two components θ'_y and θ'_z with respect to two ground-based axes of co-ordinates.

Once the integration of the components θ'_y and θ'_z has been effected, it is then necessary to remodulate the signals By and Bz which contain the integral term or, in other words, to produce by means of another change of co-ordinates a single signal B which is intended to exert action on the flight-control members.

The device of FIG. 4 performs with a satisfactory approximation this triple function of demodulation-integration-remodulation in a particularly simple manner.

It has already been shown in reference to FIGS. 3, 5, 6 and 7 that the sector and brush switching device as herein above described carries out with sufficient approximation a change of co-ordinates on the signal which is applied thereto. This change of co-ordinates can be carried out by the switching device both in the direction of integration of a signal and in the direction of reading of said signal.

A switching device of this type is therefore capable of converting the signal θ' into two signals which represent a sufficient approximation of the ideal terms

$$1_y=\theta' \cos \omega t$$

and

$$1_z=\theta' \sin \omega t$$

which define the change of co-ordinates at the time of recording.

The terms 1_y and 1_z can also be written:

$$1_y=\frac{\theta'}{2}y(1+\cos 2\omega t)+\frac{\theta'}{2}z \sin 2\omega t$$

$$1_z=\frac{\theta'}{2}y \sin 2\omega t+\frac{\theta'}{2}z(1-\cos 2\omega t)$$

If the above terms are applied to an imperfect integrator circuit of the resistor-capacitor type, the terms of ωt are evidently eliminated on account of their high frequency, with the result that the terms which are collected at the output of the integrating circuit only contain the integral of the components of θ' with respect to fixed references, thus achieving the result which was initially contemplated.

Once the integration has been effected, the same switching device effects a change of co-ordinates in the direction of remodulation.

With a view to analyzing the operation of the device of FIG. 4 in greater detail, reference will first be made to FIG. 8 which represents a fictitious device for the assumed purpose of introducing an integral term into a feed-back system which operates wholly in ground-based references. There is again shown in this figure the rate gyroscope **6**, the sign detector **7** and the flight-control members **8***a* and **8***b*. The order signal B which is supplied from a low-impedance source (not shown) is applied across terminals **56**, **57** and transmitted to the sign detector, on the one hand directly through a resistor **58** and, on the other hand, through a circuit which operates for this input as an imperfect shunt constituted by a capacitor **59** and a resistor **60**.

The angular velocity signal θ' is transmitted to the sign detector via the circuit **60–59** which plays the part of an imperfect integrator.

A circuit of this type introduces into the control system, not only the integral of the signal θ' but also, and accessorily, the derivative of the order. The introduction

of the derivative of the order makes it possible to take into account the lateral accelerations which are required of the missile and improves the response of this latter.

The fictitious circuit of FIG. 8 must be transposed, as it were, to meet the condition of a rotating missile having a single plane of action of flight-control members.

Although the operation of the transposed circuit of FIG. 4 can be fully explained only by calculation, a simplified explanation will nevertheless be ventured upon hereunder, it being understood that this explanation is not intended to constitute a strict definition of principle and that the value of the invention is not in any sense dependent thereon.

There are again shown in FIG. 4 two imperfect integrating circuits as constituted by the capacitors **52** and **55** and the resistors **46** and **47**. As appears from the figure, as far as the networks comprising resistors **50–51** and capacitor **52**, and resistors **53–54** and capacitor **55** are concerned with respect to resistors **46** and **47**, the networks including the capacitors are switched during the rotation of the brushes, which simplifies the arrangement without any attendant disadvantage. In point of fact, it serves no useful purpose to switch over the resistors since the impedance of these latter is independent of the frequency.

The resistors **44** and **45** are associated with the resistors **46–47** serve, as has already been explained, to supply the mean value of the potentials of the brushes **33** and **35** in order to obtain steps of the type shown in FIG. 7.

The resistors **50–51** and **53–54** which are associated with the capacitors **52–55** permit the introduction of the derivative of the orders By, Bz which are applied in the form of floating potentials across the terminals **40–41** and **42–43**.

It should be pointed out that the "switching system" which is shown in FIG. 4 is an original feature and that other applications thereof could be contemplated. In order to avoid the use of brushes, it is preferable in practice to design the switching system of FIG. 4 in the form of an electronic device of the optical control type as shown in FIG. 9.

The switching elements employed in a device of this type are photodiodes **61** to **69** which are interconnected via resistors **70** to **73** and capacitors **74** and **75**.

There again appear in FIG. 9 the same reference numerals as those given in FIG. 4 in order to designate like elements and $\pm By$ and $\pm Bz$ designate respectively the direction and depth orders and the opposite voltages with respect to ground.

The photodiodes have the property of constituting a break in the circuit at the point at which they are inserted when no light shines thereon and of being conductive in both directions when light shines upon them.

The illumination of the photodiodes is effected by a lamp **76** through slits formed in a disc **77** which is caused by the missile gyroscope to rotate about the rolling axis relatively to the missile. To this end, the said disc is secured to the shaft **78** shown in FIG. 3, instead of the conductive sectors and rings.

It is to be understood that the diagram of FIG. 9 does not illustrate the actual number and arrangement of the slits and the respective positions of the disc and the photodiodes, which will be readily designed by the skilled man.

During one revolution (360°), the photodiodes **61** and **63** are thus conductive while the disc rotates from 0 to 120°, the photodiodes **62** and **64** are conductive from 180° to 300°, the photodiodes **66** and **68** are conductive from 90° to 210°, the photodiodes **67** and **69** are conductive from 0 to 30° and from 270° to 360° and the photodiode **65** is conductive from 30° to 90°, from 120° to 180°, from 210° to 270° and from 300° to 360°.

It can be demonstrated that the switched network of FIG. 9 is equivalent to that of FIG. 4.

In fact, it is apparent that the photodiodes **61** and **63** transmit the order $+By$, the photodiodes **62** and **64** transmit the order of $-By$, the photodiodes **66** and **68** transmit the order $+Bz$ and the photodiodes **67** and **69** transmit the order $-Bz$.

During certain portions of a revolution as herein above defined, one of the systems of photodiodes **61** to **64** and **66** to **69** is conductive and the other system of photodiodes is blocked whereas, during other portions of a revolution, both systems are conductive at the same time. In each system, only one pair of photodiodes is conductive at any given moment while the other pair is blocked.

The photodiode **65** transmits the step **1** when only one of the two systems is conductive and transmits the step ½ when both systems are simultaneously conductive: the sequence of steps represented in FIG. 7 is thus achieved.

The arrangement of the other elements which form part of the stabilizing device which has just been described is within the capacity of anyone skilled in the art. In particular, the sign detector can consist of a high-gain amplifier followed by an amplitude limiter which controls a bistable device.

As will be readily understood, a number of different modifications could be made in the devices which have been described in the foregoing without thereby departing either from the scope or the spirit of the invention. It should be pointed out in addition that the diagrams given in the accompanying drawings have been simplified in order that the principle of operation of the devices hereinabove described may thus be made more readily apparent.

What is claimed is:

1. An installation comprising a missile which, in flight, is in autorotation about its longitudinal axis and a remote control station for the remote control of the missile, the missile having flight control means, operable so as to generate a constant pitch control torque either in a positive or a negative direction with respect to an axis at right angles to the said longitudinal axis, receiver means for receiving remote control order signals from the remote control station, said receiver means having an output; a co-ordinate changing device connected to the output of the receiver means, said co-ordinate changing device having an output; measuring means for generating a gyrometric signal which is a function of the angular velocity of the missile, as measured in a plane at right angles to its longitudinal axis, said measuring means having an output; a sign detector having an input connected to the output respectively of the measuring means and of the co-ordinate changing device, said sign detector having an output connected to the flight-control means; and the remote control station comprising means for measuring the deviation of the position of the missile in flight with respect to the line of sight, computer means for generating order signals as a function of the said deviation, and means for transmitting the said order signals to the missile.

2. An installation as claimed in claim **1**, wherein said co-ordinate changing device comprises a gyroscope having inner and outer frames, said outer frame having an axis of symmetry which coincides with the longitudinal axis of the missile; an insulating shaft attached to said frame along said axis of symmetry; first and second pairs of diametrically opposed conductive sectors mounted on said shaft; means connecting the conductive sectors to the output of the receiver means; first and second pairs of diametrically opposed brushes co-operating with the respective conductive sectors, one brush of each pair being grounded to said frame; and circuit means connecting the input of the sign detector to the output of the measuring means and to the other brushes of said brush pairs.

3. An installation as claimed in claim **2**, wherein said circuit means include first, second and third resistors having each first and second terminals, the second terminals of said resistors being connected to the input of the sign detector, the first terminal of the first resistor being con-

nected to the output of the measuring means, and the first terminals of the second and third resistors being respectively connected to the other brushes of said brush pairs.

4. An installation as claimed in claim 2, wherein said circuit means includes a capacitor and first, second, third, fourth and fifth resistors, said fourth and fifth resistors respectively connecting the other brushes of said brush pairs to the input of the sign detector, the first resistor and the capacitor having a junction and respectively connecting the frame ground and the output of the measuring means to said junction, the second and third resistors connecting said junction to the respective other brushes of said brush, said means connecting the conductive sectors to the output of the receiver means including first and second diagonal connections across said first and second pairs of conductive sectors, and a parallel capacitor-resistor integrating circuit in each diagonal connection.

5. An installation as claimed in claim 1, wherein said co-ordinate changing device comprises a gyroscope having inner and outer frames, said outer frame having an axis of symmetry which coincides with the longitudinal axis of the missile; a shaft attached to said frame along said axis of symmetry; a slotted disc mounted on said shaft; a light source located on one side of said disc and, located on the other side of said disc, a switching network including first, second, third, fourth, fifth, sixth, seventh, eighth and ninth photodiodes adapted for being illuminated according to a predetermined sequence by the light transmitted from said source across the slotted disc, said switching network further including first and second capacitors and first, second, third, and fourth resistors, said first and second resistors having a junction point, said third and fourth resistors having a further junction point,

said first and third resistors connecting the output of the measuring means to the said respective junction points, said second and fourth resistors connecting the input of the sign detector to the said respective junction points, said fifth photodiode connecting the said junction points together, said receiver means having first, second, third, and fourth inputs, said first and third photodiodes serially connecting the first output of said receiver means to said junction point, said second and fourth photodiodes serially connecting the second output of said receiver means to said junction point, said eighth and sixth photodiodes serially connecting the third output of said receiver means to said further junction point, said ninth and seventh photodiodes serially connecting the fourth output of said receiver means to said further junction point, said first capacitor being connected across said first and second photodiodes and said second capacitor being connected across said eighth and ninth photodiodes.

6. An installation as claimed in claim 1, wherein said co-ordinate changing device includes switching means for generating during the successive cycles of the autorotation of the missile, successive stepped control signals for the missile.

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