

Sept. 19, 1961

G. B. BUSH

3,000,598

ROLL STABILIZATION SYSTEM

Filed Sept. 30, 1954

FIG. 1.

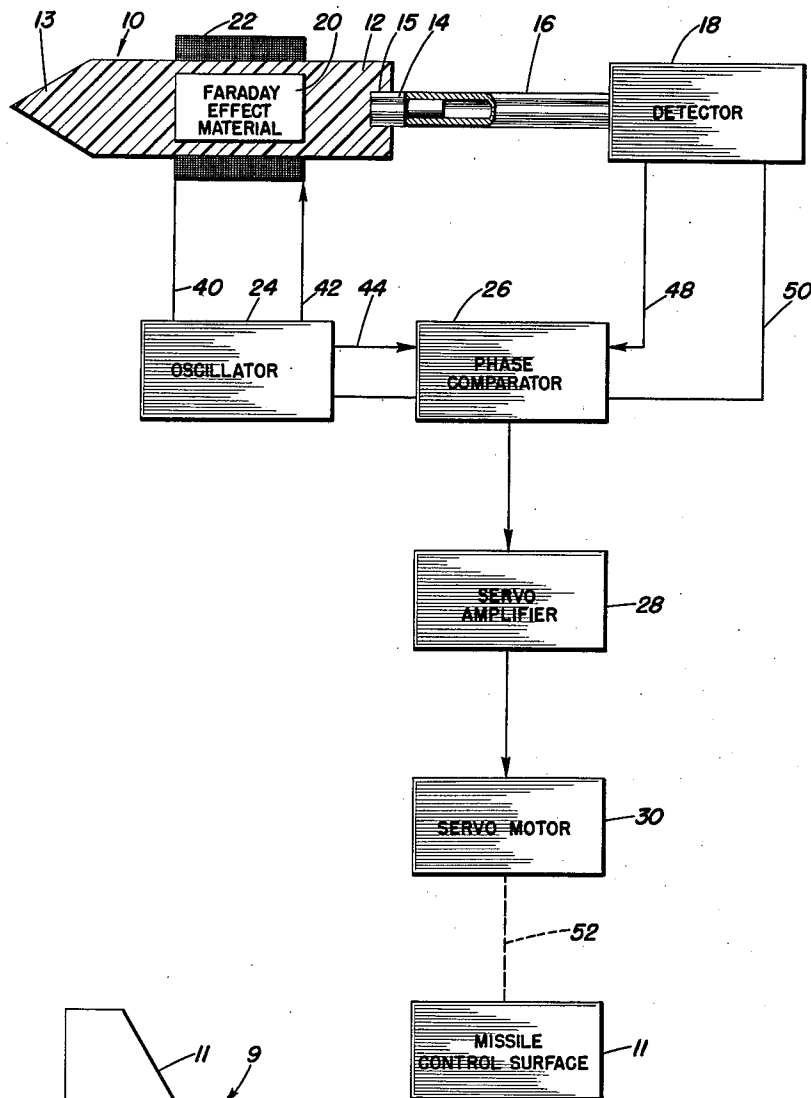


FIG. 2.

GEORGE B. BUSH

INVENTOR

BY

G. B. Bush
Q. Baxter Warner
ATTORNEYS

1

3,000,598

ROLL STABILIZATION SYSTEM

George B. Bush, Silver Spring, Md., assignor to the United States of America as represented by the Secretary of the Navy

Filed Sept. 30, 1954, Ser. No. 459,572

7 Claims. (Cl. 244-14)

The present invention relates to a roll stabilization system for use on guided missiles. In more detail, it relates to a roll stabilization system of the type which utilizes the plane of polarization of the guidance beam of electromagnetic energy as a reference plane.

In order for a guidance signal to be utilized by the missile control circuits to actuate the proper aerodynamic surfaces on the missile to steer the missile to a target, information as to the position of the missile in roll must be available. Among the prior art systems for stabilizing the missile in roll position are ones which use gyroscopes having suitable pick-off devices, or mechanical devices for modulating the received polarized electromagnetic guidance beam. Devices of both of these types are relatively complex, bulky, and require structure that is difficult to incorporate into the other guided missile structure.

It is an object of this invention, therefore, to provide a roll stabilization system for an aerial missile which utilizes the plane of polarization of the missile guide beam of electromagnetic energy as a reference plane.

It is an object of this invention to provide a satisfactory roll stabilization system for a guided missile that is simple and compact, reliable and efficient in operation, and one which can easily be incorporated into the other parts of the guided missile structure.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawing, in which:

FIG. 1 is a schematic of the roll stabilization system comprising the present invention; and

FIG. 2 is a fragmentary elevation view of the rear of a missile, illustrating the antenna in position on the missile fin.

In accordance with the present invention, the physical principle known generally as the "Faraday effect" is used to cause the plane of polarization of the electromagnetic wave of the beam, utilized for guiding an aerial missile to a target, to oscillate with respect to the axis of propagation of the beam at a known frequency. The name "Faraday effect" has been applied to the phenomenon of rotation of the plane of polarization of a polarized wave under the influence of a magnetic field.

To accomplish this effect, the receiving antenna on the guided missile includes a transmission medium, together with means for applying an alternating magnetic field to the medium which causes the plane of polarization of the guidance beam to oscillate at a fixed amplitude.

The oscillating polarization signal then is resolved by a section of transmission line or wave guide which is responsive to one plane of polarization. If the roll error of the missile from its desired position is θ and the Faraday effect medium causes a sinusoidal oscillation with angular change of $\pm a$, then the signal output after the resolver will be amplitude modulated according to the following equation:

$$E_{out} = E_{in} \cos(\theta + a \cdot \sin 2\pi ft)$$

where f is the frequency of the alternating magnetic field.

When θ is zero the amplitude of modulation is small and contains no component at the frequency f . When θ

2

is positive, the amplitude modulation component at frequency f can be in phase with the magnetic field and proportional in amplitude to θ if a and θ are not too large. When θ is negative, the amplitude modulation component at frequency f will then be reversed in phase from that which it has for θ positive and the amplitude will be proportional to the magnitude of θ , for small values of a and θ .

A detector preserves the amplitude modulation functions above described. A phase comparator converts the A.C. signal from the detector, whose phase and amplitude are a measure of roll error, into a D.C. signal whose polarity and magnitude are a measure of roll error. The phase comparator has as its reference the same A.C. signal that produces the alternating magnetic field. The common source is an oscillator.

The missile roll system is completed by using the D.C. error signal out of the phase comparator to control a servo amplifier including a shaping network which drives a servo motor. The servo motor, in turn, actuates the control surfaces of the missile. The polarities of connections are made such that the loop has negative feedback. A roll error of the missile produces a control surface movement which acts to roll the missile in the direction of a smaller error.

Referring now to FIGS. 1 and 2, there is illustrated a receiving antenna 10 which is carried on a fin surface 8 mounted on an aft portion 9 of a missile to receive the electromagnetic energy in a guidance beam projected to the missile by ground radar or the like. The antenna 10 can be mounted on the body of the missile 9, or on the wing thereof, if it is so desired. In the case of radio frequency electromagnetic energy, the antenna 10 comprises a circular dielectric lens 12 having a tapered portion 13, a round to rectangular transition portion 14 inserted in an aperture 15 in lens 12. A rectangular wave guide 16 cooperates with the transition portion 14 for feeding the received electromagnetic energy to a suitable microwave detector 18.

To cause the plane of polarization of the received wave to oscillate at a fixed frequency as it passes through the dielectric lens 12, a transmission medium or Faraday effect material 20 having a high Verdet's constant, or power of magnetic rotation, is inserted in the dielectric lens 12 in the path of a received wave, and a coil 22 is wound on the periphery of the lens 12. Examples of materials having a high specific power of magnetic rotation are phosphorus, Rochelle salt, ferrite, zinc sulfide and carbon disulfide.

An oscillator 24, connected to coil 22 by leads 40 and 42, supplies an alternating magnetic field which is aligned with the direction of propagation of the received wave. The magnetic field acts on the medium 20 to rotate the plane of polarization of the wave passing through the medium 20 with respect to its initial plane of polarization. As the magnetic field generated by the coil 22 reverses its direction, the direction of rotation also reverses with the plane of polarization therefore oscillating about the axis of propagation at the same frequency as the frequency of the current from the oscillator 24. However, if the missile carrying the antenna 10 has a roll error, the modulation of the signal supplied to the detector 18 will have a phase and amplitude proportional to this error.

The outputs of the oscillator 24 and the detector 18, which are connected to a phase comparator 26 by leads 44 and 46, and leads 48 and 50, respectively, are supplied to the phase comparator 26 which converts the A.C. phase and amplitude to a D.C. control signal with corresponding polarity and magnitude which is used to rotate the missile to the desired roll position. This is

3

accomplished by supplying the output of the phase comparator 26 to a servo amplifier 28 which includes a shaping network. The shaping network included in amplifier 28 controls the phase and amplitude of the detected roll signal in order that the roll system will be stabilized and have optimized characteristics. The output signal from amplifier 28 operates a servo motor 30.

The servo motor 30 is connected by a suitable mechanical linkage 52 to a control surface 11 of missile 9 to actuate the aerodynamic control surface 11, thereby rotating the missile and its antenna 10 back into alignment with the plane of polarization of the received wave so that the remaining amplitude modulation produced by the angular oscillation of the plane of polarization is very small.

A further improvement in the system can be obtained by substituting for the plane polarized resolver an elliptically polarized resolver which has the effect of improving the linearity of the output signal for a large error angle.

The practical utilization of this system may require an additional roll sensing device, such as a gyroscope, to resolve the ambiguity that this system has between right side up and upside down.

Instead of utilizing the Faraday effect as previously described, the same result can be achieved by utilizing the "Kerr effect" where a lateral electrostatic field would be used to rotate the plane of polarization. Different types of materials can be used to obtain the "Kerr effect," particularly nitrobenzene and like materials.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is, therefore, to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A roll stabilization system for a guided missile having an aerodynamic control surface and a servo system associated therewith, comprising a receptor for electromagnetic energy, said receptor including a transmission medium having significant power of magnetic rotation of the plane of polarization of said electromagnetic energy, an alternating current signal generator providing an oscillating magnetic field, means for applying said oscillating magnetic field to said medium for causing the transmitted plane of polarization of said electromagnetic energy to oscillate with respect to the initial plane of polarization thereof, means for resolving the resulting oscillating plane of polarization, thereby producing an amplitude modulation of the electromagnetic energy at the frequency of the alternating magnetic field with depth of modulation and phase proportional to roll angular error of the missile, means for detecting the electromagnetic energy, means for comparing the detected signal with the alternating voltage of said signal generator to produce a D.C. signal which is proportional to roll error in polarity and magnitude, said D.C. signal being utilized to operate said servo system whose output orients said aerodynamic control surface, which, in turn, rolls the missile in a direction to reduce the roll error.

2. A roll stabilization system for a guided missile having an aerodynamic control surface, comprising, an antenna located on the missile for receiving electromagnetic energy from a missile guidance beam, said antenna including a transmission medium having a significant power of magnetic rotation of the plane of polarization of said electromagnetic energy, an alternating current signal generator providing an oscillating magnetic field, means for applying said oscillating magnetic field to said medium for causing the transmitted plane of polarization of said electromagnetic energy to oscillate with respect to its initial plane of polarization, means for resolving the resulting oscillating plane of polarization, thereby producing an amplitude modulation of the electromagnetic energy at the frequency of the alternating

4

magnetic field with depth of modulation and phase proportional to roll angular error of the missile, means for detecting the electromagnetic energy, means for comparing the detected signal with the alternating voltage of said signal generator to produce a D.C. signal which is proportional to roll error in polarity and magnitude, and a servo system operated by said D.C. signal to orient said aerodynamic control surface, which, in turn, rolls the missile in a direction to reduce the roll error.

3. In a roll stabilization system for a body having a control surface, means for receiving electromagnetic energy propagated from a remote point to said body including a receptor rigidly mounted on said body which is plane polarized, said means including a transmission medium having a significant power of magnetic rotation of the plane of polarization of said electromagnetic energy, an alternating current signal generator producing an oscillating magnetic field, means for applying said oscillating magnetic field to said medium for causing the transmitted plane of polarization of said electromagnetic energy to oscillate with respect to its initial plane of polarization, means for resolving the resulting oscillating plane of polarization to produce an amplitude modulation of the electromagnetic energy at the frequency of the alternating magnetic field with depth of modulation and phase proportional to roll angular error of said body, means for detecting the electromagnetic energy, means for comparing the detected output with the alternating voltage of said signal generator to produce a mechanical motion, said mechanical motion having one sense of motion for a detected output at the oscillating frequency that is in phase with the oscillation and an opposite sense of motion for a detected output that is in phase opposition to the oscillation, and servo-operated means associated with said control surface for physically utilizing said mechanical motion to rotate the angular orientation of the receiving means around the axis of propagation of the electromagnetic wave.

4. In a roll stabilization system for a body, means for receiving electromagnetic waves propagated from a remote point to said body including a receptor rigidly mounted on said body which is essentially plane polarized, means for cyclically oscillating the polarization of said electromagnetic waves around the axis of propagation of said waves by applying a cyclically varying magnetic field to a material having a Faraday effect which is placed in the path of propagation of said electromagnetic waves, means for detecting the electromagnetic energy received by said receptor, means for comparing the detected output with the frequency of cyclical variation of the magnetic field to produce a mechanical motion, said mechanical motion having one sense of motion for a detected output at the oscillating frequency that is in phase with the oscillation and having an opposite sense of motion for a detected output that is in phase opposition to the oscillation, and means for physically utilizing said mechanical motion to rotate the angular orientation of the body, and, therefore, the receptor around the axis of propagation of the electromagnetic wave.

5. In a roll stabilization system for a guided missile having a control surface, means on the missile for receiving electromagnetic energy from a missile guidance beam, said means including a transmission medium having a relatively high power of magnetic rotation of the plane of polarization of said guidance beam, an alternating current signal generator producing an oscillating magnetic field, means for applying said oscillating magnetic field to said medium for causing the plane of polarization of said electromagnetic energy to oscillate with respect to the axis of propagation to said guidance beam, means for detecting polarization oscillations, said means being arranged to have a fixed orientation with respect to the longitudinal axis of said missile, means for comparing the phase of the detected modulation with the phase of the alternating voltage of said signal gen-

5

erator to produce a measure of roll error in both magnitude and direction, and means associated with said last mentioned means to utilize said roll error to eliminate the change in roll position of the missile by adjusting said control surface.

6. In a system for detecting roll error of a body, means on said body for receiving energy from an electromagnetic beam of radiation, said means including a transmission medium having a relatively high power of magnetic rotation of the plane of polarization of said beam, an alternating current signal generator producing an oscillating magnetic field, means for applying said oscillating magnetic field to said medium for causing the plane of polarization to oscillate with respect to the axis of propagation to said beam, means for detecting polarization oscillations, said means being arranged to have a fixed orientation with respect to the principal axis of said body, and means for comparing the phase of the detected modulation with the phase of the alternating voltage of said signal generator, whereby the signal output of said system is a measure of roll magnitude and direction of said body.

7. A roll stabilization system for a guided missile having an aerodynamic control surface and a servo system associated therewith, comprising a receptor for electromagnetic energy, said receptor including a transmission medium having significant power of magnetic rotation of

6

the plane of polarization of said electromagnetic energy, an alternating current signal generator producing an oscillating magnetic field, means for applying said oscillating magnetic field to said medium to cause the transmitted plane of polarization of said electromagnetic energy to oscillate with respect to the initial plane of polarization thereof, means for resolving the resulting oscillating plane of polarization, thereby producing an amplitude modulation of the electromagnetic energy at the frequency of the alternating magnetic field with depth of modulation and phase proportional to roll angular error of the missile, means for detecting the electromagnetic energy, and means for comparing the detected signal with the alternating voltage of said signal generator to produce a signal representative of roll error of said missile in both magnitude and direction, said signal being utilized to operate said servo system to adjust said aerodynamic control surface to roll stabilize said missile.

References Cited in the file of this patent

UNITED STATES PATENTS

2,051,537	Wolff	Apr. 18, 1936
2,362,832	Land	Nov. 14, 1944
2,513,367	Scott	July 4, 1950
2,616,640	Bedford	Nov. 4, 1952