Sept. 2, 1958 W. A. JOERNDT 2,850,251
ROLL COMPENSATOR FOR GUIDED MISSILES
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FIG. 1.

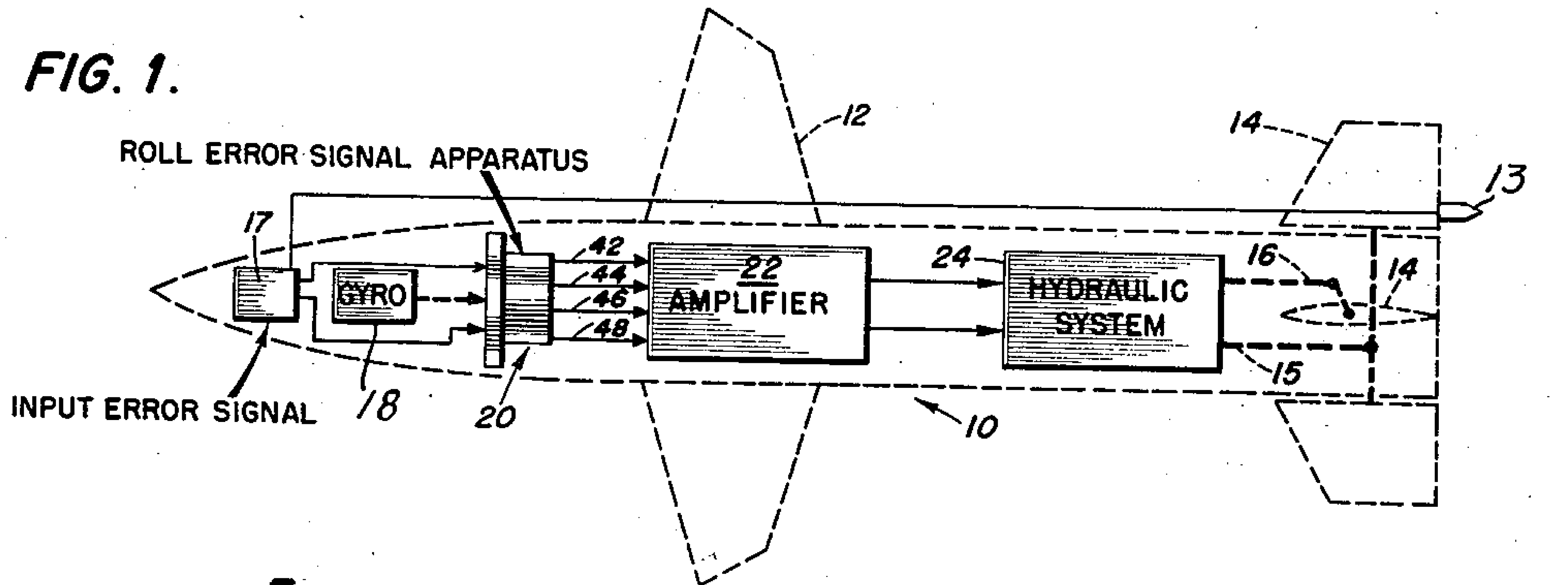


FIG. 2.

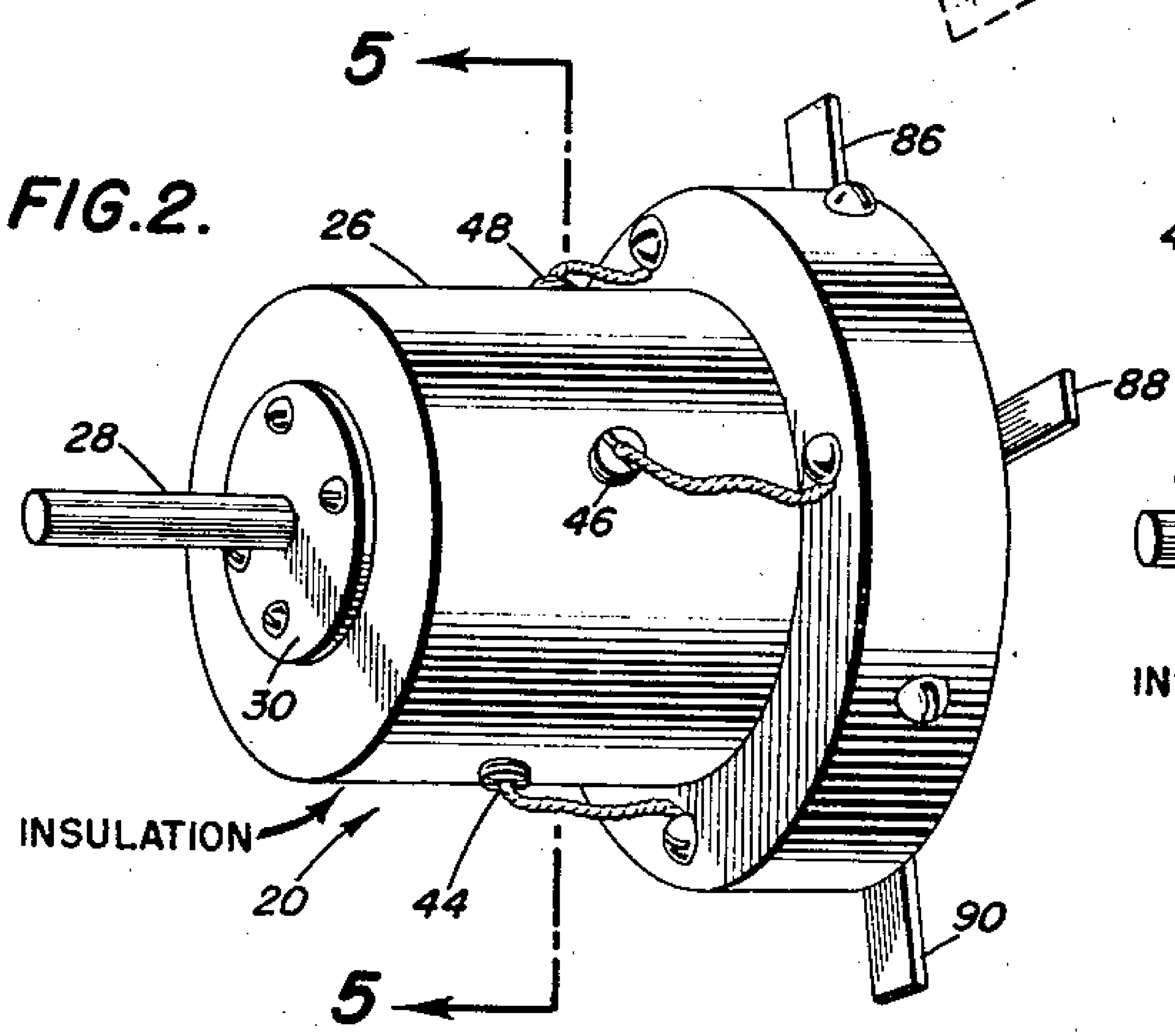


FIG. 3.

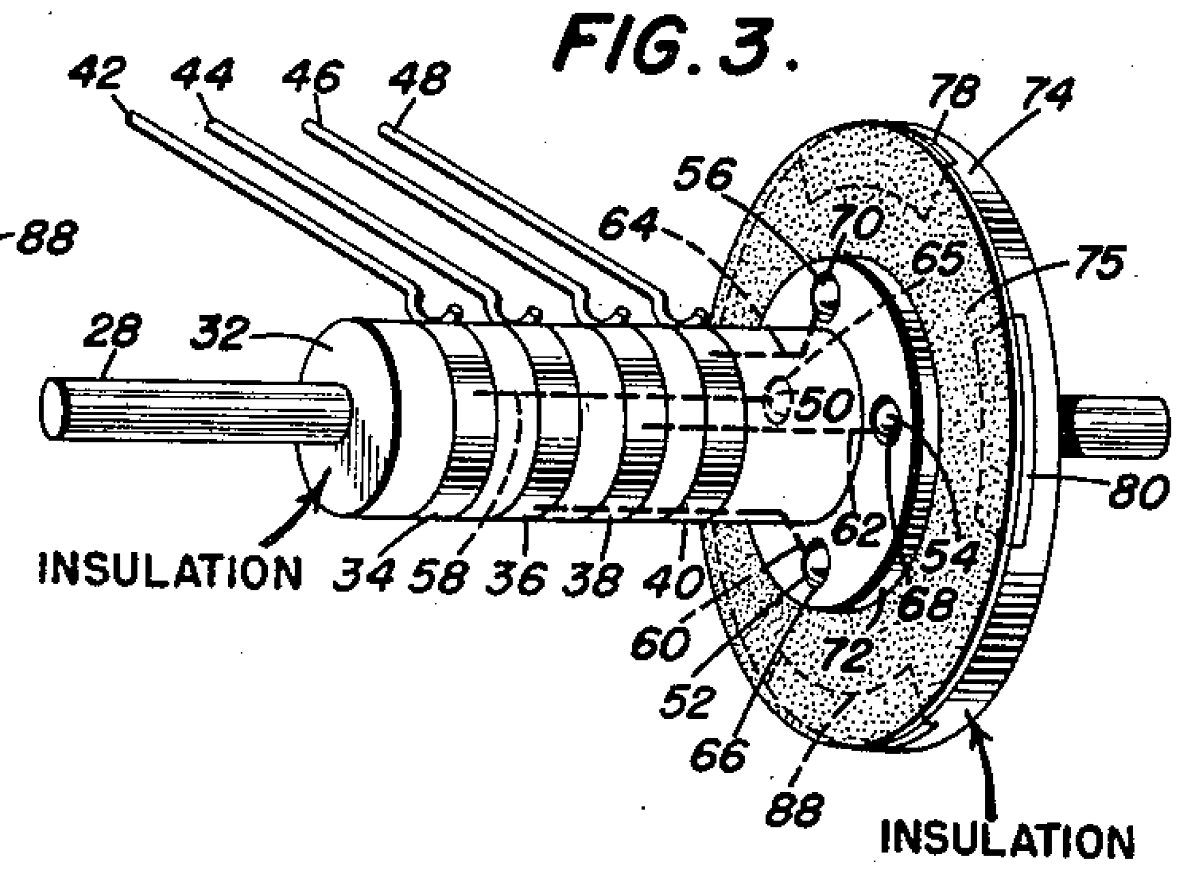
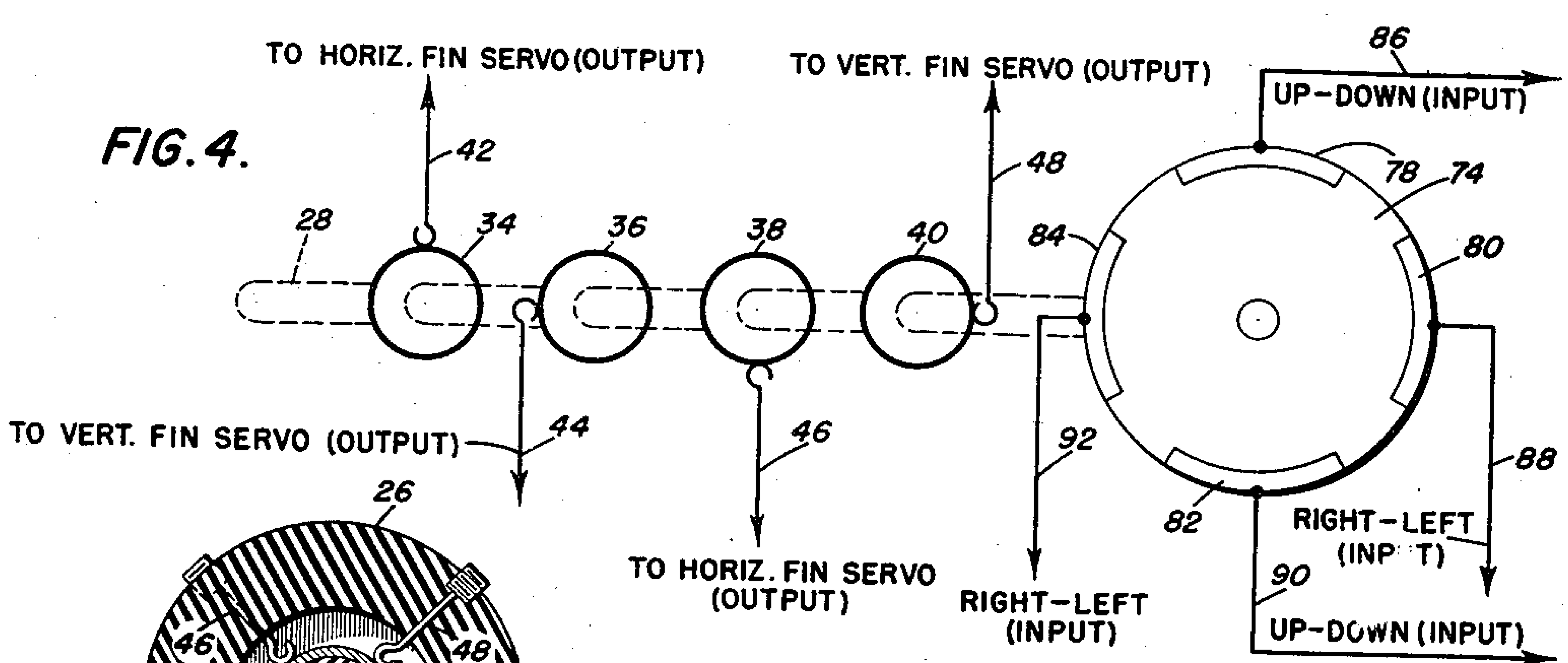


FIG. 4.



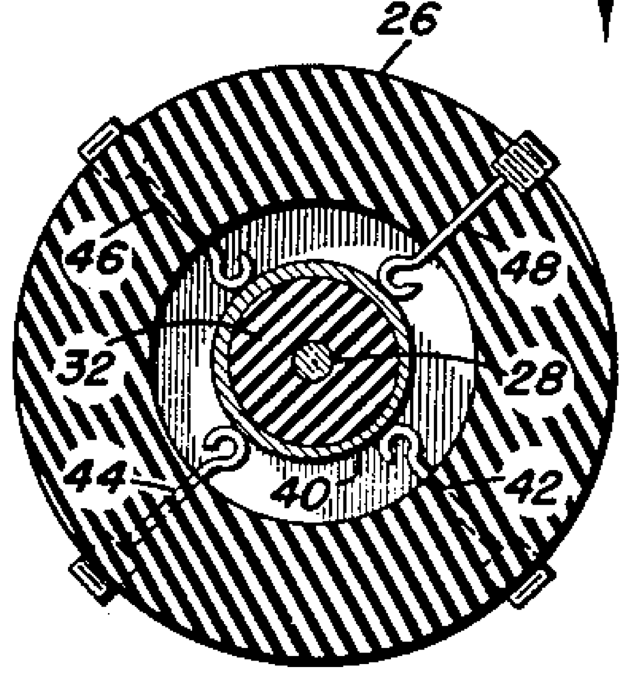


FIG. 5.

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ROLL COMPENSATOR FOR GUIDED MISSILES

Filed April 8, 1954 2 Sheets-Sheet 2

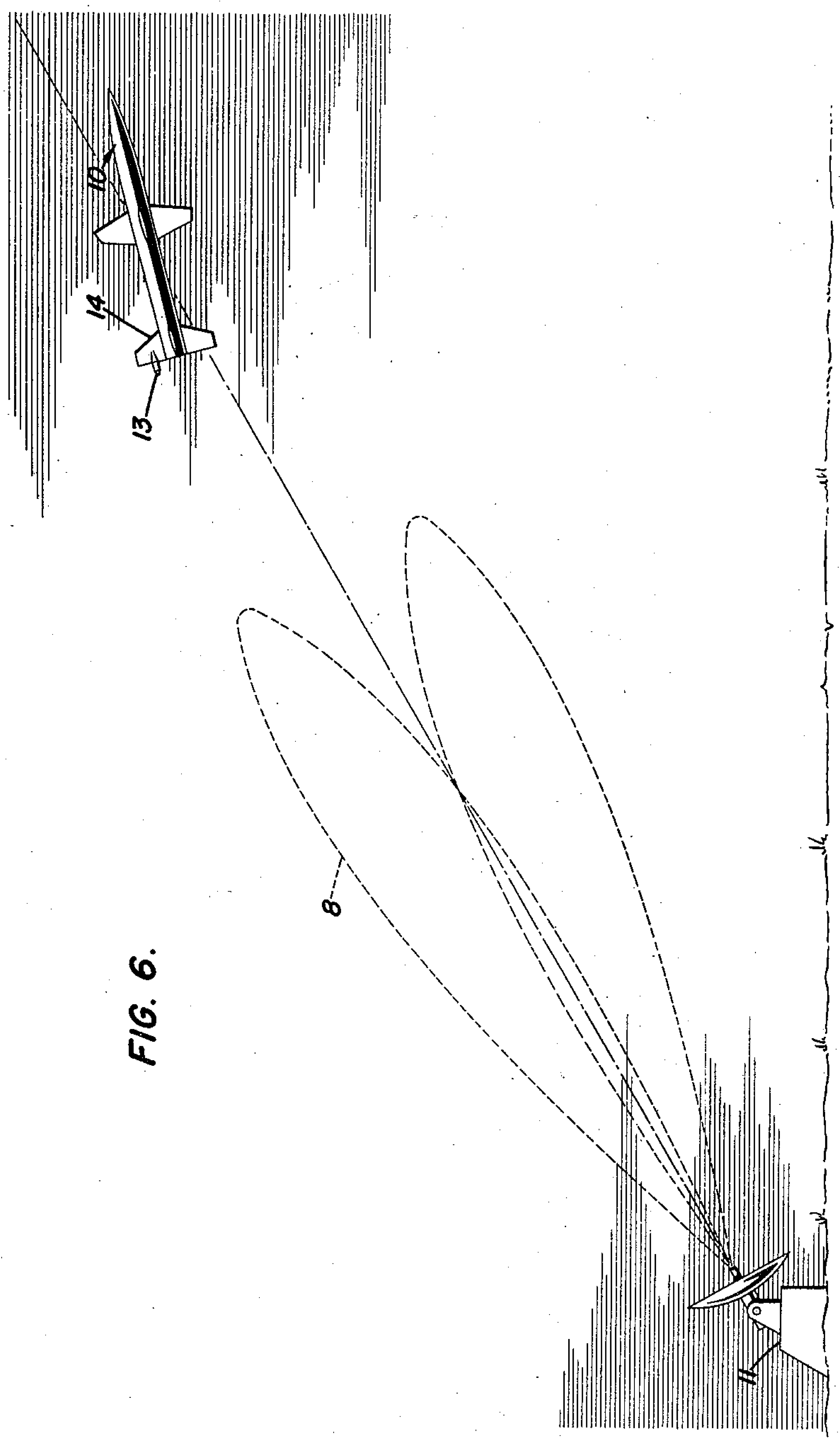

FIG. 6.

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ROLL COMPENSATOR FOR GUIDED MISSILES

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Application April 8, 1954, Serial No. 421,991

5 Claims. (Cl. 244—14)

This invention relates in general to roll compensation systems for guided missiles, and in particular it relates to apparatus for generating roll compensated guide beam error signals when a guided missile is rolling.

It is one of the objects of this invention to provide apparatus for modifying target misalignment signals of a guided missile, and for adjusting the position of the fins to correct for guide beam misalignment to roll compensate the missile.

Another object of the invention is to provide apparatus for applying guide beam error signals modified to compensate for roll of a missile to the servo-stabilizing system of a guided missile in order to roll compensate the missile.

Still another object of the invention is to provide apparatus for determining and applying guide beam error signals modified to roll compensate a missile, which is compact, easy to manufacture and install in the missile, and efficient and reliable in operation.

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 conjunction with the accompanying drawings wherein:

Fig. 1 is a schematic of a guided missile, showing apparatus for generating roll compensated guide beam error signals;

Fig. 2 is a perspective view of the apparatus for determining roll compensated guide beam error signals, embodying features of the invention;

Fig. 3 is a perspective view, partly schematic, of the apparatus shown in Fig. 2, with the casing removed, and showing in detail some of the features of the invention;

Fig. 4 is a schematic of the circuitry for the apparatus of Figs. 2 and 3;

Fig. 5 is a cross section along line 5—5 of Fig. 2; and

Fig. 6 is a schematic illustrating the position of the missile in a guidance beam of electromagnetic energy.

In accordance with the invention, apparatus is provided for determining and applying guide beam error signals compensated for roll movements of a guided missile to the servo-stabilizing system thereof. This apparatus comprises means for producing a resistance path variation responsive to roll movements of the missile. These means comprise a plane resistance surface which is immovable relative to the missile, with one or more pairs of contacts bearing on the resistance surface and being rotatable relative to the resistance surface as by a free gyroscope stabilizing the contacts against roll. Any shifting of the surface relative to the contacts produces a change in the path of current flow in the surface. The contacts pick up parts of the voltage drops due to the guide beam error signals. These modified error signals are fed to amplifying means where they are amplified and are used to control a hydraulic servo system. The hydraulic servo system, in turn, is utilized to adjust

the position of the missile fins to return the missile to the guide beam.

Referring now to Fig. 1 of the drawings, there is shown an aerial missile **10** of either the rocket or ramjet type, which has a plurality of fixed wings **12** for flying the missile and a plurality of fins **14** for steering the missile while it is in aerial flight along a trajectory.

As illustrated in Fig. 6, a standard radar transmitter **11**, located at a remote point in space and having a pulse repetition rate frequency modulated in synchronism with its scan rate, is utilized to project a guidance beam **8** of electromagnetic energy to guide the missile **10**.

When the missile **10** is not travelling centrally along the guide beam, input error signals are picked up by an antenna **13** mounted on one of the fins **14** of the missile **10** and are fed to suitable conventional means, such as a guide beam error measuring device **17**, and thence to a guide beam error signal modifying apparatus **20**. A free gyroscope **18**, is mechanically connected to a shaft **28** (Fig. 2) in such a way that when rolling of the missile occurs, this shaft will be stabilized against turning by the gyroscope **18**. Apparatus **20** modifies the up-down misalignment signal, as well as the right-left misalignment signal of the missile **10** responsive to roll. These modified guide beam error signals are then fed to a suitable amplifying means **22**, and are used to control a hydraulic servo system **24**. The latter, in turn, controls the position of the missile fins **14** to correct the heading of the missile **10**.

Referring now in particular to Fig. 2 there is shown the guide beam error signal modifying apparatus **20** in perspective. This apparatus can conveniently be enclosed in a casing **26** of suitable insulating material. The casing **26** supports the shaft **28** which is mechanically connected to the gyroscope **18**. A suitable bearing **30** is provided at one end of the casing **26** to provide support for the shaft **28**. This bearing also serves as a cover or closure for one end of the casing **26**.

Shaft **28**, as illustrated in Fig. 3, carries a cylinder **32**, which is likewise made of a suitable insulating material, and upon which are located four (4) slip rings **34, 36, 38**, and **40**. Upon the slip rings rest the ends of four (4) conductors **42, 44, 46**, and **48**, which are made of relatively fine wire and which are arranged to bear resiliently on the slip rings **34, 36, 38**, and **40**, respectively.

Slip rings **34, 36, 38**, and **40**, in turn, are connected to contacts **50, 52, 54**, and **56**, by means of leads **58, 60, 62**, and **64**, as shown by dotted lines. Contacts **50, 52, 54**, and **56** may be of any desired shape. However, they are shown here as metal spheres which are carried in corresponding apertures **65, 66, 68**, and **70**, in an insulating disk **72**. Insulating disk **72** is secured to the cylinder **32** so as to rotate therewith when the latter rotates with shaft **28**.

It is to be understood, furthermore, that while two types of contact members are shown, namely, the resilient type of contacts for the conductors **42, 44, 46**, and **48**, which engage the slip rings **34, 36, 38**, and **40**, respectively, and the metal spherical type of contacts **50, 52, 54**, and **56**, the springs and the spheres may all be of a single type. Regardless of the type of contacts associated with the disk **72**, each such contact will bear resiliently against the adjacent surface of a stationary disk **74**.

The stationary disk **74**, which is mounted in the enlarged portion of the casing **26**, has a coating of high-resistance material on the face **75** thereof adjacent disk **72**. For example, this material can comprise carbon or an equivalent thereof. However, a suitable coating would be one such that a one (1)-inch square made thereof would have a resistance of the order of 400 ohms between opposite sides. This coating, in turn, may be carried or placed on any suitable insulating material, on the disk **74**.

Electrical contact is made with this coating by means of four (4) metal terminal members 78, 80, 82, and 84, such as illustrated in Fig. 4. These metal contact members are arcuate, and each is equivalent in length to 45°. These contact members 78, 80, 82, and 84, are arranged symmetrically around the disk 74. Conductors 86, 88, **90**, and **92** connect to the terminal contacts **78**, **80**, **82**, and **84**, respectively, with opposite ones, for example, 86 and 90, and 88 and 92, constituting paired circuit conductors for receiving the respective misalignment signals from the error signal guide beam apparatus 17, that is, the up-down and right-left misalignment signals due to errors in direction of travel of the missile 10.

An electrical field is set up in the plane of the disk 74, the value of which at any point is the vector sum of the electrical fields due to the misignment signals applied at the pairs of terminals 78, 82, and 80, 84. Assuming, for example, the application of instantaneously equal misalignment signals at contact terminals 78, 82, and **80**, **84**, the field vector in the neighborhood of the central region of the disk 74, upon which the contacts 50, 52, 54, and 56 bear, would bisect the angle between the component fields. If it is assumed that the electrical field is uniform over the central region bounded by the contacts 50, 52, 54, and 56, then the potential difference between opposite contacts 50 and 54, or 52 and 56 is given by the projection of the resultant vector upon the line joining such pairs of contacts multiplied by their distance apart.

Let F_x+F_y be the component fields in the disk 74 due to the separate misalignment signals, r the distance of the contacts 50, 52, 54, and 56 from the axis of rotation of the shaft 28, and θ the angle between the line joining opposite contacts **52**, **56** or 50, 54, and the y and x axes of the disk 74.

Then the resultant field vector

$$F=\sqrt{F^2{}_x+F^2{}_y}$$

making an angle ϕ with the y axis such that

$$\phi=\frac{F_x}{F_y}$$

If the applied voltage varies, the angle ϕ varies according to the foregoing relationship. The voltage developed between a pair of contacts, such as 50 and 54, will then be given by the expression

$$V_2=2r(F_x.\cos\,\theta-F_y.\sin\,\theta)$$

and the voltage developed between contacts 52 and 56 will be given by the expression

$$V_1=2r(F_y.\cos\,\theta+F_x.\sin\,\theta)$$

It will be seen that if θ is also the angle of roll of the missile 10, and the voltages or potential V_1 or V_2 are now applied to the appropriate fin servo mechanism, such as the hydraulic servo mechanism 24, modification of the original error signals to take care of roll of the missile can be achieved.

In accordance with the principles of vector combination, the two signals, which are at right angles to one another for the system indicated in Fig. 4, pass through the apparatus without mutual interference. These two signals may then be conveyed simultaneously to the amplifier arrangement 22, where they are amplified, and to the hydraulic servo stabilizing system 24.

The operation of the invention will now be explained. After the aerial missile 10 has been launched by suitable launching means (not shown) and is in flight along its trajectory, it is assumed that the missile is subjected to rolling movements. The casing 26, of the guide beam error signal modifying apparatus, is stationary with respect to the missile **10**. However, means such as the free gyroscope 18, is connected to the shaft 28 in such a manner that, when rolling of the missile occurs, this shaft 28 will be stabilized against roll by the gyroscope 18.

If now the up-down misalignment signal is applied to the terminals **86** and **90**, and the right-left misalignment signal to the terminals 88 and **92**, then currents will flow in the resistance surface of the disk **74** between the respective terminals **78** and 82, or 80 and 84, and of proper values to represent the guide signal errors existing at the moment. The contacts **50**, **52**, **54**, and **56**, which bear on the resistance surface of disk **74**, will thus pick up proportional parts of the respective voltage drops produced by the guide signal error currents. For example, if constant D. C. voltages are maintained across terminals **86** and **90**, upon rotation the contacts **42** and **46** will derive a simple harmonic voltage, that is, a sine wave voltage, therefrom. Likewise, if constant direct current voltages are maintained across terminals **88** and **92**, upon rotation of shaft **28** the contacts **44** and **48** will derive a simple harmonic voltage, that is, a sine wave voltage, therefrom. These voltages are then fed simultaneously to the amplifier **22** and to the hydraulic servo system **24** and the latter is used to control the fins **14** of the missile **10** through suitable mechanical linkages, such as **15** and **16**.

As previously stated, either spheres or springs may serve as the actual contact elements. However, it has been found that it requires more torque to operate the roll error signal apparatus **20** with ball contacts than when thin wires are used. Therefore, it is preferred to use the thin wires, since this imposes less load on the gyroscope **18**, and, consequently, does not cause serious precessional movements of the gyroscope.

It is also to be pointed out that instead of having the contact rings **34**, **36**, **38**, and **40** rotate, and the springs of contacts **42**, **44**, **46**, and **48** remain stationary, these elements may be interchanged, so that the cylinder **32** will carry wire springs and the slip rings **34**, **36**, **38**, and **40** will then be mounted in the stationary casing **26**. This form may require more torque to operate it, inasmuch as the contacts will then be more remote from the axis of the shaft **28**.

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. In combination, an aerial missile, means for generating a beam of electromagnetic energy for guiding said missile, means in said missile for generating an electric signal representative of guide beam error, apparatus for modifying said guide beam error signal responsive to rolling movement of said missile, said apparatus including a casing having a resistor therein, said resistor having spaced terminals and a substantially flat surface between said terminals, a pair of spaced contacts bearing on said surface, and a shaft mounted to rotate in said casing, said resistor and pair of contacts being carried by said casing and shaft in such a manner that relative rotation of said shaft and casing will shift said contacts angularly over said surface, thereby producing a variation in the resistance path between said contacts and terminals which is a function of said guide beam error signal.

2. In combination, an aerial missile, means for generating a beam of electromagnetic energy for guiding said missile, means in said missile for generating electric signals representative of up-down and right-left guide beam error, apparatus for modifying said guide beam error signals responsive to rolling movement of said missile, said apparatus including a casing having a resistor therein, said resistor having up-down signal terminals and right-left signal terminals and a substantially flat surface therebetween, two pairs of spaced contacts bearing on said surface, with the line connecting said contacts

of one pair of spaced contacts being substantially at right angles to the line joining said contacts of said other pair of spaced contacts, a shaft mounted to rotate in said casing, said resistor and two pairs of contacts being carried by said casing and shaft in such a manner that relative rotation of said shaft and casing will shift said two pairs of contacts angularly over said surface, thereby providing variations in the resistance paths between said contacts and terminals which are a function of said error signals.

3. In combination, an aerial missile having movable fins, means for generating a beam of electromagnetic energy for guiding said missile, means in said missile for generating electric signals representative of up-down and right-left guide beam error and having a plurality of fins for up-down and right-left steering of said missile, apparatus for modifying said guide beam error signals responsive to roll movements of said missile, including means having up-down and right-left beam error signal contacts and a resistance surface therebetween, a free gyroscope, at least one pair of contacts bearing on said resistance surface and being stabilized against roll by said gyroscope, means for picking said modified beam error signals from said resistance surface, means for amplifying said modified signals, and means for utilizing said signals to control said fins of said aerial missile for steering it into alignment with the guide beam.

4. In combination, an aerial missile having movable fins for steering said missile, means for generating a beam of electromagnetic energy for guiding said missile, means in said missile for generating electric signals representative of guide beam error, apparatus for modifying said beam error signal responsive to roll movement of said missile, said apparatus including a first element carried by said missile to partake of said roll movement of said missile, a second element coacting with said first element, means for varying the relative positions of said elements in response to rolling movement of said missile, resistance-varying means for modifying said beam error signals re-

sponsive to the relative motion of said elements, means for picking said modified beam error signals from said resistance-varying means, means for amplifying said modified signals, and means for utilizing said amplified signals to control said movable fins for steering said missile into alignment with said guide beam.

5. In combination, an aerial missile having a plurality of movable fins for steering said missile, means for generating a beam of electromagnetic energy for guiding said missile, means in said missile for generating an electric signal representative of guide beam error, apparatus for modifying said guide beam error signal responsive to roll movement of said missile, said apparatus including a casing, said casing having a resistor therein, said resistor having spaced terminals for receiving the beam error signal and a substantially flat resistor surface therebetween, a free gyroscope, at least one pair of spaced contacts bearing on said surface and being stabilized against rolling by said gyroscope, a shaft mounted to rotate in said casing, said resistor and said pair of contacts being carried by said casing and shaft in such a manner that relative rotation of said shaft and casing will shift said contacts angularly over said surface, said contacts constituting means for picking a modified beam error signal from said resistance surface, means for amplifying said modified signal, and means for utilizing said amplified signal to control said fins of said missile in order to steer the latter into alignment with said guide beam.

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