AUTOMATIC SELF-GUIDANCE SYSTEM FOR MOVABLE OBJECTS

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By Attorney
My invention relates to a homing missile responsive to target radiation. More specifically my invention relates to means to adjust the course of travel of an aerial bomb toward a target emitting radiation.

In the usual practice of bombing from aircraft the pilot maintains a steady course while the bombardier aligns the target in the bomb sight and at the prescribed state of alignment releases the bombs. The accuracy of this method of bombing depends upon the skill of the pilot and bombardier and upon favorable conditions of wind and visibility. Once the bombs are released, there is no way of compensating for errors in judgment of the pilot or bombardier or for unpredictable variations in air currents which may cause the bomb to miss the target.

Recently, methods have been devised to control by means of a radio wave the path of a bomb during its fall to the target. This enables an operator to correct an error in the initial aim of the missile. The effectiveness of this method of correcting initial errors in aim depends upon the reliable performance of the radio control equipment and upon the prompt and skilled action of the operator in transmitting the course correction required.

To assist the operator in such correction missiles have been equipped with television conversion and transmitting equipment. Radio control and intelligence-relaying equipment frequently fail to function adequately either as a result of equipment failure or as a result of unfavorable radio wave propagation. In addition, the enemy may apply countermeasures in the form of “jamming” or interfering radio signals. Systems have also been devised for causing aerial bombs to home continuously and automatically while falling upon certain kinds of targets. These systems have the advantage of largely eliminating the element of human error in judgment and of eliminating the possibility of failure of radio control or intelligence-relaying equipment since these equipments are not used. It is only necessary to achieve moderate accuracy of initial aim of this type of bomb in order that the target shall be within the field of view of the automatic homing system. However, the automatic homing systems herefore devised and known have relatively complex scanning mechanisms and signal-utilizing electric circuits. Some have vacuum tube circuits requiring delicate and critical adjustments to be maintained in flight. In all cases a smaller, lighter and more reliable functioning equipment is desirable in order to increase the explosive load and the certainty of hitting the target.

Ideally, if the axis of flight of a missile is maintained in continuous alignment with a target proceeding at a lesser rate than itself, the missile will eventually strike the target in spite of evasive maneuvers on the part of the target. It should be noted, however, that this is true for practical applications only where the velocity of the missile is much greater than the velocity of the target and where the means contained in the missile for maintaining its alignment of axis of flight with the target is accurate and quick of response.

One of the means of maintaining this alignment or homing course is to incorporate in the missile a viewing device having its field of view coaxial with the line of flight utilizing for corrective effect the position of a target image with respect to the four quadrants about the center of the field of view. By this method the center of the field of view becomes the origin while the remainder of the field of view may be defined in positive and negative values of “X” and “Y” coordinates or axes. Any deviations from the homing course may be represented in terms of four variations of positive or negative values of image displacements from the origin along the “X” and “Y” axes in the field of view. It remains to devise a means of converting these values into electrical and mechanical forms responsive in such a manner that the missile's course is altered and the target image returned to the origin.

My invention is characterized by the fact that simple means are provided for viewing the target and for producing the necessary aerodynamic correction to maintain the homing course.

My invention is further characterized by the fact that the signal provided by the target is substantially constantly effective to alter the course of the missile.

My invention is still further characterized by the fact that the image of the target in the viewing device is effective to cause simultaneous correction of the direction of flight of the missile in two mutually perpendicular planes.

In accordance with one aspect of my invention a configuration of temperature-sensitive resistive material having a high coefficient of resistance is used to produce simultaneous correction in two planes.

In accordance with other aspects of my device, a temperature-sensitive resistance element is used which produces a corrective signal which is an increasing function of the displacement of the target image from the optical axis.

Further, in accordance with my invention, I provide a temperature-sensitive cell, the elements of which are excited by alternating potentials at different frequencies.

In accordance with one aspect of my invention, a temperature-sensitive resistance element may be used continuously to view a target without the intervention of mechanical chopping means.

One of the objects of my invention is to provide a superior automatic homing system suitable for aerial bombs.

Another object is to provide an automatic homing system which largely eliminates the element of human error in judgment.

Another object is to provide a homing system independent of radio-control or intelligence-relaying systems.

Another object is to provide a homing system which cannot be “jammed” by enemy radio counter measures.

Another object is to provide a more reliable automatic homing system by virtue of having a simple target-responsive device and relatively simple signal-utilizing electric circuits which do not depend upon maintenance of delicate or critical adjustments during flight.

Referring to the drawing:

FIGURE 1 is a block diagram showing the relative location of the various components in a homing missile constructed in accordance with my teachings.

FIGURE 2 is a simplified circuit diagram showing temperature-sensitive resistance elements excited by two different frequencies together with the associated amplifying filtering and servo devices.

FIGURE 3a shows the driving of the exciting alternators by means of a wind-driven propeller.

FIGURE 3b is a vertical sectional view of the device of FIGURE 3a.

FIGURE 4 shows the use of a mechanical chopping device used in conjunction with temperature-sensitive elements constructed in accordance with my design.

FIGURE 5 shows a means of constructing a tempera-
ture sensitive element utilizing series-connected resistance elements.

FIGURE 6 shows the use of parallel-connected temperature-sensitive elements.

FIGURE 7 shows the use of series-connected resistance elements in adjacent non-overlapping relation.

FIGURE 8 shows a resistance element construction usable with the remainder of my device but of less inherently satisfactory design.

FIGURE 1 shows an outline and block diagram of a housing missile in which the housing 10 includes the explosive lead 12 and the housing equipment referred to generally by the numeral 14. At the rear of the missile and provided over control surfaces 16 and vertical control surfaces 18. At the nose of the missile is placed the optical system indicated generally by the numeral 20 passing radiation to a temperature or radiation-sensitive cell 22. The output from the temperature-sensitive cell is fed into a preamplifier 24, into power amplifiers 26 and 27 and thence to the servo operators controlling the control surfaces. One servo mechanism 28 is provided for controlling the surface 18 while another set of servo equipment 30 is used for controlling surface 16.

FIGURE 2 shows a simplified circuit diagram showing the main features of my device. The lens 50 or other suitable optical system focuses radiation on the temperature-sensitive cell 22. The optical system and the temperature sensitive cell are preferably mounted in an optical head 32. The temperature-sensitive cell 22 is preferably centered with respect to the axis of the optical system.

In the preferred embodiment of my device the temperature-sensitive cell 22 consists of four elements which will be designated for the sake of convenience as the "right" element 34, the "left" element 36, the "up" element 38 and the "down" element 40. The "right" element is fed into a winding 42 of an input transformer 44 and the "up" element 38 is fed into a secondary winding 46 of this transformer. The "down" and "left" elements are similarly fed into windings 48 and 50 respectively of transformer 52. The secondary winding 54 of transformer 44 is fed into the grid circuit of one side of a double channel preamplifier 24. The second winding 56 of transformer 52 is fed into the other channel of the preamplifier 24. I have shown vacuum tubes 58 and 60 as illustrative to the two channels of the amplifier 24.

Resistance elements 38 and 40 are fed by a source 62 of alternating potential at frequency \( F_1 \), while the resistance elements 34 and 36 are excited by means of an alternating source 64, at a frequency which we shall designate as \( F_2 \). At the output of the preamplifier 24, filter 66 allows passage of a signal of frequency \( F_1 \) to the power amplifier 26. Another filter 68 allows passage of a signal at frequency \( F_2 \) from tube 58 to the power amplifier 27. In like manner filter 70 allows a signal of frequency \( F_1 \) to be passed to power amplifier 26 and a filter 72 passes a signal at a frequency \( F_2 \) to power amplifier 27.

For the sake of a diagrammatic simplicity the resistance elements 34, 36, 38 and 40 have been shown as non-overlapping. However, in the preferred form of my device the resistance elements are considerably widened so that resistance element 34 extends upward to cover half of the area occupied by element 38 and downward to cover half the area occupied by element 40. In like manner, resistance element 36 is arranged to cover half the area occupied by elements 38 and 40 respectively.

This type of structure will be more fully explained in connection with the explanation associated with FIGURES 5, 6, 7 and 17. The resistance elements may consist of any material having a large temperature coefficient of resistance at the designed operating temperature. An example of such a material is columbium nitride cooled to approximately 15 degrees Kelvin. While no means has been shown for cooling the temperature-sensitive cell 22, it will be obvious to one skilled in the art that cooling means such as liquid air may be used in the optical head or associated with the cell 22 itself.

In the embodiment of my device shown in FIGURE 2, the radiation-sensitive elements are excited in diametrical pairs by alternating currents sources 62 and 64 which differ in frequency. Since the power requirements are extremely low, the exciting current may be produced by electronic oscillators. For maximum simplicity, however, I prefer to obtain alternating current from a pair of generators driven by propellers mounted in the slip-stream of the missile. In FIGURES 3a and 3b, I have shown one design of alternators. The alternating voltage is obtained from the windings associated with the armatures 62 and 64 respectively. Cooperating with such armatures are propellers 74 and 75 which are constructed, as is well known, as magnetic fields. A large number of such fields may be employed to cause the frequency of the output to be maintained at a substantially constant value, a governor 76 of any well-known type may be provided. Since it will be necessary for the governor to absorb energy, I prefer to place the governor in the slip stream for maximum cooling effect. If desired the propellers may be mounted in a duct 77. It will appear to one skilled in the art that a small constant speed direct current motor may also be used to drive the alternators.

The operation of the device thus far disclosed is as follows: as source of radiation, a source is shown, the power plant, is located on the optical axis and aligned with the missile, its projected image will fall on the optical axis at the center of the temperature-sensitive cell 22.

Under such conditions, the current flowing through resistance element 34 will be the same as that flowing through resistance element 36. Accordingly, the voltage produced at the secondaries 54 and 56 of transformers 44 and 52 respectively, will be equal. Thus the output of tube 58 fed through filter 66 will equal the output of tube 60 fed through filter 72. Included in the amplifier 27 is provided a circuit of any one of many types of circuitry, skilled in the art which is responsive to the difference between the signal received from filter 68 and that received from filter 72. Since under centered target conditions these signals are equal and the input of the amplifier 27 therefore balanced, no signal will be transferred from the amplifier 27 to the servo device 30. It may likewise be shown that with the target vertically centered between temperature sensitive elements 38 and 40, the signal at a frequency \( F_1 \) will be balanced at the input of the power amplifier 26 and no motion of the servo device 28 will result to change the vertical direction of motion of the missile.

Normally, the image of the target will not be exactly aligned with the missile and the image of the target will be displaced from the optical axis. In order that the operation of the device may be more fully understood under these conditions we shall assume that the relative motion between the missile and the target has caused the image of the missile to fall in the "up-right" quadrant on elements 34 and 36. The effect of the image on these two elements may be discussed separately. In the case of the image falling on element 34, the temperature of the element 34 will be raised and its resistance accordingly changed. This will cause an unbalance of the signal at a frequency \( F_1 \) at the transformer secondaries 54 and 56. Such unbalance will cause a different magnitude of signal to arrive at amplifier 27 through filter 68 as compared to the signal arriving at this amplifier through filter 72. Such unbalance causes motion of the servo device 30 tending to move the missile to the right or to the left as required to center the target between temperature-responsive elements 34 and 36. By the same reasoning, it may be shown that the unbalance between the temperature-sensitive elements 38 and 40 causes a change in the image of the target on element 38 causes a different magnitude of signals to arrive at amplifier 26 through filter 66 as compared to that passed through filter 70. This unbalance causes motion of the servo device 28 in such a direction as to center the image of the target between temperature-responsive elements 38 and 40.
In FIGURE 4, I have shown another embodiment of my homoing missile in which the exciting cell voltage is obtained from a direct current source and the pulsating output signal is obtained through the use of a mechanical chopper. As in the previous embodiment, the optical system is represented by the lens 20. Intercepting the optical path is the chopper 80 which may consist of a disc, half of which is in contact and half of which has been covered with an opaque substance. The chopper may be driven by any convenient means, as for example by the wind-driven propeller 82, the velocity of which may be kept practically constant by means of a governor 84. Temperature-sensitive elements 38 and 40 obtain D.C. potential from a D.C. current source 86, while elements 34 and 36 obtain their D.C. supply from source 88. Source 86 is connected to one side of the primaries 90 and 92 associated with transformers 94 and 96 respectively; like-wise, source 88 is connected to windings 98 and 100 of transformers 102 and 104 respectively. Secondary windings 106 and 108, 118 and 112 are respectively connected to the preamplifier tubes 114, 116, 118 and 120. Amplifier means 25 and 27 are provided which are similar to the means provided in connection with the previous embodiment. Servo equipment 28 and 30 may be the same as that employed in connection with FIGURE 2.

Again, as in the case of the device of FIGURE 2, movement of the target image from the central position, for example, in such a direction as to fall upon temperature-sensitive elements 34 and 38 will be accompanied by an unbalance of the system with FIGURE 4. The resistance of the element 34 as compared to the element 36 will cause unlike currents to flow through primary windings 98 and 100 of the transformers 102 and 104. These currents will, of course, be pulsating due to the chopping action of the chopper disc 80. As the result of this unbalance, plate current will be unbalanced in tubes 114 and 116. The magnitude and direction of the unbalance will be interpreted by amplifier 27 and operation of the servo device 30 will be produced. In like manner, unbalance between temperature-sensitive ele-ments 38 and 40 will result in motion of the servo device 28. The motion of each of the servo devices will be in such a direction as to restore the image of the target to the centered position, in other words, to align the missile and the target.

The chopper disc 80 is preferably of such a size as to completely cover the area of the temperature-sensitive elements 34, 36, 38, or 40. With this arrangement the pulses of plate current of two associated preamplifier tubes will be out of phase and it will be necessary for the comparison means included in the amplifier to compare two signals out of phase by 180 degrees. If desired, the size of the chopper disc may be increased so that radio- tion is simultaneously removed and simultaneously applied to diametrically-opposed temperature-sensitive ele-ments. In this way, the current pulses originating in such diametrically opposed elements will be in phase and somewhat simpler comparison means may be used.

As stated above, many designs of means responsive to the difference between the two input signals applied to the input of amplifier 26 or amplifier 27 will appear to one skilled in the art. One way in which such difference may be utilized is by feeding the amplified signals to be com-pared into two coaxial magnetic coils connected in bucking relation as shown in FIGURE 4. The current flow in one of the coils as compared to the other would be evidenced by motion of a spring-centered solenoid engaging both of the coils, according to well known differential current relay techniques, generally illustrated in Ham mond 1,307,850.

It should be noted that in both of the embodiments discussed above means are provided for causing the signal appearing in the circuit of the sensitive elements to be of a cyclicly-varying nature, even where radiation of a constant value is being received. This enables the use of A.C. amplifiers which are inherently more stable and more practical to use than D.C. amplifiers.

FIGURE 5 shows the preferred embodiment of cell construction in which temperature-sensitive elements 34, 36, 38 and 40 are connected in diametrical pairs with the resistance material in the form of a single filament. For diagrammatic simplicity elements 34 and 36 are shown dotted. In order that the displacement of the target from the central position toward the periphery may cause an increased signal as the radial displacement is increased, I prefer to increase the density of the resistance elements in a progressive manner with increasing radius. This may be done by causing the loops of resistance material to be more closely spaced at points away from the center or may be caused by changing the resistance of the filamentary material along its length. In this manner, the signal produced by a target image may be increased proportionately with the distance from the center of the cell if so desired.

FIGURE 6 shows an arrangement of resistive material in which the strands of the resistive material are in parallel rather than in series relation.

In FIGURE 7 is shown an arrangement which has the advantage that the resistance elements need not be placed in perpendicular relation to the irradiating surface. The embodiment interrelating resistance to simplify the cell struc-ture. By so doing, it is possible to eliminate a layer of insulating material which would otherwise have to be used between two objects occupying the same area, and thereby to simplify the device. This embodiment of the invention has been discussed, it is to be understood that it may also be ap-
applied to other vehicles and for other uses in both peace and war. While I have shown and described but a
limited number of forms which my invention may take, it will appear to those skilled in the art that various
changes and modifications may be made without departing from the spirit and scope of my invention as set forth in the appended claims.

The invention described herein may be made or used by or for the Government of the United States for governmental purposes without the payment to me of any royalties thereon or therefor.

I claim:

1. A radiation detector comprising focusing means having an optical axis, a first pair of radiation sensitive elements in spaced relation normal to and diametrically centered on said axis, a second pair of radiation sensitive elements in similar spaced relation normal to and diametrically centered about said optical axis, said second pair of elements lying substantially in the plane of and at right angles to said first pair of elements, an alternating current source operating at a first frequency, a second alternating current source operated at a second frequency, said pairs of elements energized by said alternating current sources respectively, amplifier means responsive to the voltage across each element of said pairs of elements, first servo means controlled by said amplifier and responsive to said first frequency, second servo means controlled by said amplifier responsive to said second frequency whereby radiation falling on at least one of said elements causes operation of at least one of said servos.

2. The subject matter as claimed in claim 1 wherein said alternating current sources comprise wind-driven alternating current generators.

3. The subject matter as claimed in claim 1, said alternating current sources consisting of electronic oscillators operating at two different frequencies.

4. A radiation detector comprising an optical system having an optical axis and a focal plane normal to said axis, a plurality of pairs of radiation-sensitive resistances placed in said focal plane, a plurality of alternating current sources supplying resistance elements, servo operator means controlled by said amplifier means, filter means associated with said servo means and said amplifier means whereby a signal of predetermined frequency is effective to cause operation of a given servo means.

5. A radiation detector comprising an optical system having a focal plane and an optical axis, a pair of radiation-sensitive resistance elements placed in said focal plane on opposite sides of said optical axis, a second pair of radiation-sensitive resistance elements in said focal plane at right angles to said first pair of resistances, a source of alternating voltage at a first frequency, a source of alternating voltage at a second frequency, said sources supplying said first and second pairs of resistance elements respectively, a two channel amplifier, having a first channel excited by the voltages across one of each of said pairs of resistances and a second channel excited by the voltages across the remaining resistance elements, two servo operators controlled by said amplifier, filters interposed between said amplifier and said servos whereby signals of said first frequency are fed to one of said servo operators and signals of said second frequency are fed to the other of said servo operators.

6. A homing missile responsive to radiation including an optical system having an optical axis, a first pair of radiation-responsive elements disposed diametrically upon said optical axis to receive the projected image of a remote source of radiation, said pair of elements substantially covering the field of view of said optical system, a second pair of radiation-responsive elements located substantially in the same plane as said first pair of elements but at substantially right angles thereto as measured about said optical axis and each member thereof covering substantially half of the area of each of said first pair of elements, a pair of alternating current sources respectively energizing said pairs of radiation-sensitive elements, amplifier means excited by the voltage appearing across said radiation-responsive elements, servo operator means controlled by said amplifier means, control surfaces to control the direction of flight of said missile, said control surfaces respectively attached to said servo operators whereby each member of said pairs of missiles is caused to be constantly directed toward a remote source of radiation.

7. A homing missile as claimed in claim 6 wherein the design of radiation-responsive elements is such that the signals produced by the action of a target image on each member of said pairs of elements is increased in accordance with the distance from said optical axis that said target image falls on said radiation-responsive element member.

8. A homing missile responsive to a distant source of radiation including an optical system having an axis, a first diametrically-disposed pair of radiation-sensitive elements centered on said optical axis and arranged to receive an image of a remote source of radiation, a second diametrically disposed pair of radiation-sensitive elements substantially coplanar with said first pair of elements and at 90 degrees thereto, each of said pairs of elements substantially coextensive with the other said pair, chopping means interposed in said optical system to cyclically prevent radiation from reaching said elements, amplifier means connected to said elements, plural servo operator means connected to and controlled respectively by said pairs of radiation-sensitive elements, control surfaces respectively operatively connected to said servo means and associated therewith to maintain a direction in space wherein the image of said remote source of radiation tends to be maintained on said optical axis.

9. The subject matter as included in claim 8 including propellant means located in the slip stream of said missile for driving said chopper means.

10. A radiation-responsive homing missile including an optical system having an optical axis and arranged to focus a target image on a focal plane, a first diametrical pair of heat-responsive elements located in the region of said focal plane and disposed on opposite sides of said optical axis, a second diametrical pair of heat-responsive elements located in the region of said focal plane and disposed on opposite sides of said optical axis, said second pair of heat-responsive elements substantially at right angles to said first pair of heat-responsive elements, said pair of elements acting on said elements to provide a cyclically varying output signal comprising a shaft having one or more propellers mounted thereon and positioned to receive air from the slipstream of said missile, said propellers consisting at least partially of magnetic material and having one or more armatures of magnetic material respectively cooperating magnetically therewith and including output windings, amplifier means excited by said heat-responsive elements, servo operators respectively connected to said amplifier means and controlled by said pairs of heat-responsive elements whereby the radiation falling upon said elements is effective to guide said missile in two degrees of freedom.

11. The subject matter as claimed in claim 10, including a governor mounted on said shaft whereby a substantially constant shaft speed is obtained, said governor in contact with the air of said slipstream whereby the heat generated in said governor is removed.

12. The subject matter as claimed in claim 10, including an air duct, said propellers mounted in said air duct, said armatures mounted outside said air duct in the region of said propellers allowing magnetic cooperation between said propellers and said armatures.

13. A radiation-responsive homing missile including an optical system having an optical axis and arranged to focus
a target image on an area centered in a focal plane of the optical system, a first pair of heat-responsive elements substantially in said focal plane and separately disposed across both upper quadrants of said area and both lower quadrants of said area, respectively, from said axis, a second pair of heat-responsive elements substantially in said focal plane and separately disposed across both left quadrants of said area and both right quadrants of said area, respectively, from the axis, whereby one element of each pair is responsive to a target image regardless of the quadrant in which the image occurs, alternating current controlling means acting on said elements to provide alternating current output signals controlled by said elements, amplifier means excited by said heat-responsive elements, servo operators connected to said amplifier means and selectively controlled by said pairs of heat-responsive elements, servo drives for guiding means of said missile and controlled by said operators, whereby the radiation falling on said elements is effective to guide said missile in two degrees of freedom simultaneously.

14. The homing missile of claim 13 in which the heat-responsive elements of the upper quadrants of said area and lower quadrants of said area are constructed and arranged for image sensitivity progressively greater as distance from said axis increases and the heat-responsive elements of the left quadrants of said area and right quadrants of said area are constructed and arranged for image sensitivity progressively greater as distance from said axis increases.

15. A radiation responsive homing missile including an optical system having an optical axis and arranged to focus a target image on an area centered in a focal plane of the optical system, first and second heat responsive elements substantially in said focal plane and separately disposed across first and second halves of said area as bisected by a first axis passing through the optical axis, third and fourth heat responsive elements substantially in said focal plane, and separately disposed across opposing halves of said area as bisected by a second axis passing through the optical axis, said second axis being perpendicular to the first axis, whereby two elements are responsive to a target regardless of its position in the area, alternating current control means for said elements to provide alternating current output signals of amplitude controlled by said elements, amplifier means excited by each of said heat responsive elements, servo operators connected to said amplifier means and selectively controlled by said heat responsive elements in opposing halves of the area, servo drives for guiding means of said missile controlled by said operators, whereby the radiation falling on said elements is effective to guide said missile in two degrees of freedom simultaneously.

16. The homing missile of claim 15, in which the heat responsive elements of the halves of said area possess image sensitivity which is progressively greater for regions thereof which are more distant from the bisecting axis than regions which are closer to the bisecting axis.

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