March 11, 1958 R. W. KETCHLEDGE 2,826,380

STEERING SYSTEMS

Filed Dec. 28, 1944

FIG. 1

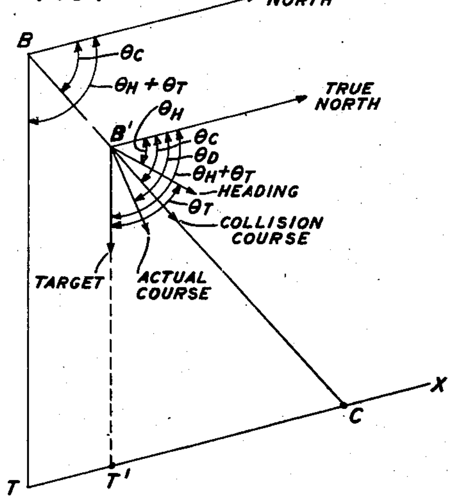


FIG. 2

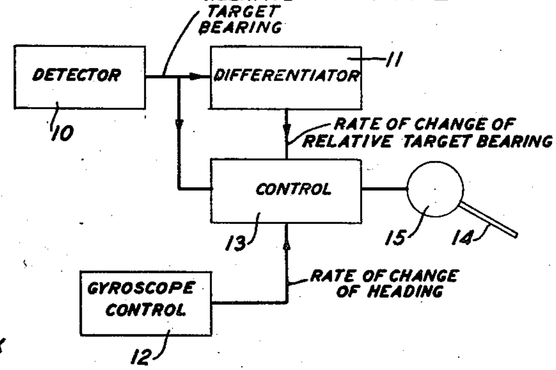
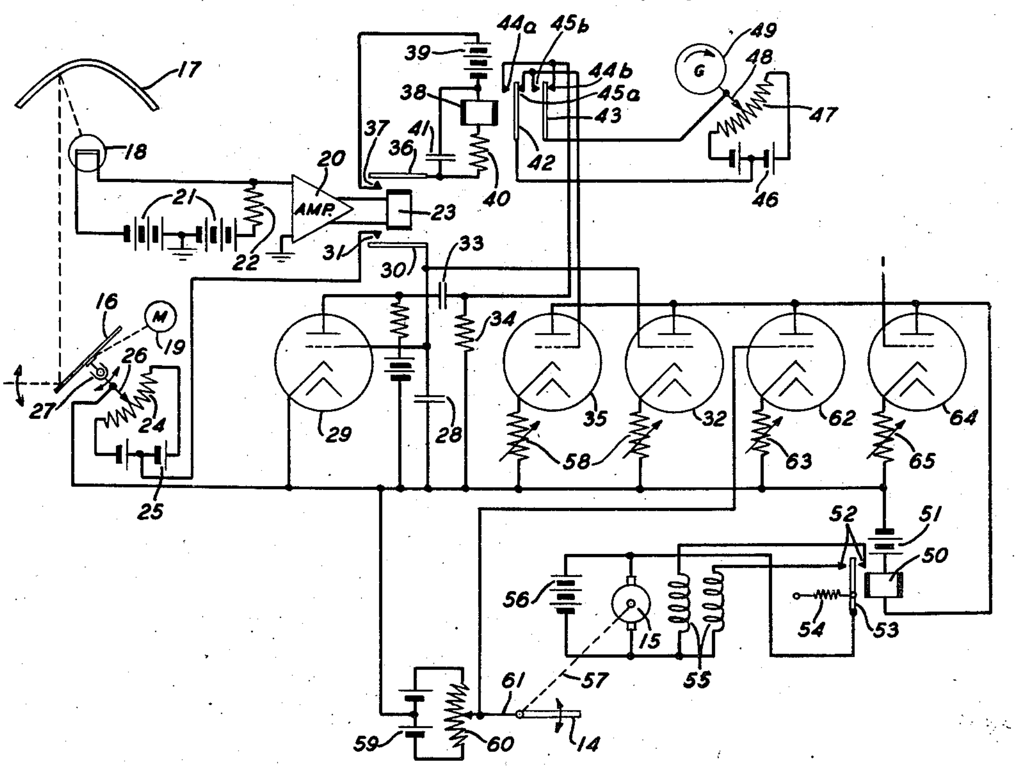


FIG. 3



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STEERING SYSTEMS

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This invention relates to steering systems and, more particularly, to such systems responsive to wave energy emanating from a target and adapted to guide a moving body to the target in accordance with information derived from such energy and detected at the body.

In one, and a specific, aspect, this invention relates to a steering system for a self-propelled aerial bomb, i. e., in the form of a pilotless aircraft, which is particularly suitable for use against objects, such as ships or power plants, the temperature of which is substantially different from that of the surrounding area.

A moving body, such as an aerial bomb, at any initial position relative to a target, which may be stationary or moving, may follow any one of a number of courses in traveling to the target. For example, in the case of a moving target, the body or bomb in its flight might be controlled so that it was headed continuously toward the target, whereby it would follow a generally curvilinear homing course. Also, for this case, the bomb would meet the target if it were steered along a collision course, i. e., a straight line at such angle to the path followed by the target that at some point the positions of the bomb and target would coincide.

For the case where the bomb follows a homing course, it must be steered in accordance with the relative bearing of the target with respect to the bomb. For the case where the bomb is to follow a collision course, it must be steered in accordance with the true target bearing, i. e., its bearing relative to a reference direction such as true north. As will be pointed out in some detail hereinafter, the steering function for collision course steering necessitates information as to both rate of change of relative target bearing and rate of change of bomb heading throughout the flight of the bomb.

Guidance of a body, such as a bomb, to a target along a collision course has the advantage that such course represents the shortest path that can be traversed by the bomb in reaching the target for any given target and bomb speeds. Thus, flight along a collision course represents, in one sense, an increase in bomb range as compared with that for flight over a homing course. Further, collision course steering, as will be demonstrated hereinafter, has inherent advantages from the standpoint of steering control and of bomb maneuverability in the vicinity of the target. On the other hand it may have a disadvantage at large distances from the target from the standpoint of accuracy of steering information required, due to the small value, at such distances, for the rate of change of relative target bearing term involved in the steering function.

Homing course steering, on the other hand, entails less stringent requirements upon bearing information necessary to effect steering at great distances between bomb and target. However, such steering may have the disadvantage, particularly in the case of bombs of substantial size, in the vicinity of the target, of restricted accuracy due to limited maneuverability of the bomb.

One general object of this invention is to improve steering systems of the type adapted to guide a body to a target in accordance with information as to the position or position and course of the target derived from wave energy emanating from the target and detected at the body.

More specifically, objects of this invention are to:

Realize guidance of a body, by a steering system of the type above noted, along a collision course;

Increase the steering accuracy of such a sysem;

Enable attainment of desired control characteristics, specifically a relatively high stiffness of control, for such a system;

Reduce the stringency of design requirements for wave energy responsive steering systems, particularly such systems intended to be responsive to energy emanating from a distant source; and

Obtain stability of control in wave energy responsive steering systems for moving bodies.

In one illustrative embodiment of this invention, a steering system for an aerial bomb, which may be in the form of a pilotless aircraft generally of known construction mechanically, comprises a detector of infra-red radiation which is actuated to scan a field repeatedly in one dimension, e. g., horizontally or vertically, a steering member, such as a rudder, an actuator for the steering member, and a resolving circuit for converting energy emanating from a target in the field noted and received by the detector into a control signal for causing operation of the actuator and, hence, of the steering member, to guide the bomb to the target. In one form, the detector comprises a mirror, receptive to infra-red radiation, which is oscillated to scan a prescribed field, and a highly sensitive bolometer associated with the mirror to receive infra-red radiation reflected from the mirror.

In accordance with one feature of this invention, the resolving circuit is constructed and arranged to provide a signal proportional to the relative target bearing, which signal is applied to the control circuit for the actuator for the steering member in such manner that, in the absence of other controls, the bomb is steered along a homing course.

In accordance with another feature of this invention, the resolving circuit is constructed and arranged to provide also a signal proportional to the rate of change of relative target bearing and means are provided for producing a third signal proportional to rate of change of bomb heading. The two signals noted are combined and applied to the control circuit for the actuator for the steering member in such manner that, in the absence of other controls, the bomb is steered along the collision course.

In accordance with a further feature of this invention, the homing course and collision course signals are applied simultaneously to the control circuit noted in such relation that when the bomb is at a relatively great distance from the target it is steered substantially along a homing course whereas at relatively small distances from the target it is steered substantially along the collision course.

In accordance with still another feature of this invention, means are provided for reversing the sense of the rate of change of heading signal, as applied to the control circuit aforenoted, when no target energy is received by the detector, whereby, for this condition, the signal noted exerts a stabilizing effect upon the steering control.

The invention and the above-noted and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing in which:

Fig. 1 is a diagram illustrating relationships and parameters of bomb and target positions and motions, which will be referred to hereinafter in the discussion of certain principles involved in this invention;

Fig. 2 is a diagram, in functional block form, of a steering system constructed in accordance with this invention; and

Fig. 3 is a circuit diagram of a steering system illustrative of one embodiment of this invention.

Referring now to the drawing, in Fig. 1, a bomb and target are indicated at arbitrary positions B and T respectively, and with the connecting or base line BT therebetween at an arbitrary angle to true north. Assume that the target is moving in the direction of the line TX and that the bomb is moving in a direction generally toward this line. For given initial positions of the bomb and target and given velocities, and assuming that the bomb is steered toward the target, there exists some point at which the bomb and target will meet. It will be apparent that the bomb may be directed or steered along a number of different paths to collide with the target. For example, if it follows a true collision course it will travel along the straight line BC and arrive at the point C at the same time as the target. Also, for example, it may follow a generally curvilinear or homing course and meet the target at a point on the line TX.

The actual course, θ_D, at any instant may be as indicated by the arrow so designated in Fig. 1. The heading, θ_H, of the bomb at any instant may not coincide with the actual course, due to, for example, wind and other factors causing the bomb to turn, and may be as indicated by the arrow designated "Heading" in Fig. 1, to produce a relative target bearing θ_T.

If the bomb follows a true collision course, at some time subsequent to that corresponding to the positions B and T, the bomb and target will be at the positions indicated by B' and T' in Fig. 1. It will be seen that a true collision course is followed, if the true bearing, $(\theta_H+\theta_T)$, of the target remains constant. Thus, to realize collision course travel of the bomb, the steering can be accomplished in terms of the true target bearing, that is, by effecting steering in accordance with the time derivative of the true target bearing. Mathematically, the steering function for collision course steering may be expressed, then, as

$$F_C=\frac{d\theta_H}{dt}+\frac{d\theta_T}{dt} \tag{1}$$

where F_C is the steering function, t is time and θ_H and θ_T are as defined above. If the bomb is following the collision course, F_C is zero; if it deviates from this course, the magnitude and direction of the deviation of F_C from zero are indicia of the steering correction required to return the bomb to this course.

In homing course steering, the bomb is guided to maintain it headed toward the target. Thus, as is apparent, the steering function for a homing course is

$$F_H=\theta_T \tag{2}$$

where F_H is the steering function and θ_T is as defined above. This function may be considered as a measure of the steering correction requisite to return the bomb to a homing course if it deviates from such a course.

Certain characteristics of the steering functions and of the terms involved therein must be considered in the design of any particular steering system. Two factors of particular moment in the evaluation of the performance of a steering system are the stiffness of control that may be realized and the stability of the system. Stiffness of control may be defined as the ratio of the steering effect, expressed, for example, in terms of amplitude of rudder deflection, to the off course angle of the body, e. g., bomb, being steered. Stability may be defined as freedom from erratic steering behavior such as large amplitude, self-sustained, oscillations of the body under steering control, about the on course position.

In the collision course steering function as expressed in Equation 1, supra, the rate of change of heading term

$$\frac{d\theta_H}{dt}$$

is important from the standpoint of both stiffness of control and stability. If this term is omitted from the steering function, correction of the course will result in reduction of the magnitude of the term

$$\frac{d\theta_T}{dt}$$

Consequently, the stiffness of control is limited and may not be of sufficient magnitude to provide accurate steering. Specifically, for the condition under consideration, the limitation on stiffness of control is to a maximum angular rate of course correction equal to the rate of change of true target bearing.

However, if this term, i. e.,

$$\frac{d\theta_H}{dt}$$

is included in the steering function, the correction of the course of the body being steered results in changes of both terms of the steering function in somewhat compensatory manner. For example, if the body is off course in such position that

$$\frac{d\theta_T}{dt}$$

is positive, a correction of the course will reduce this term. However, such correction will change the term

$$\frac{d\theta_H}{dt}$$

in such manner as to produce a positive value therefor equal to the reduction in the term

$$\frac{d\theta_H}{dt}$$

Hence, the course correction rate is substantially unlimited and any desired stiffness of control can be realized.

It may be noted, however, that in itself the steering function term

$$\frac{d\theta_H}{dt}$$

represents an unstable control and this characteristic must be taken into account in the construction of any particular steering system. Thus, utilizing only a portion of this control in the steering system results in increased stability but also entails some reduction in stiffness of control. Also, inasmuch as the control represented by the terms

$$\frac{d\theta_H}{dt}$$

is unstable, as noted above, it is advantageous that this control be disabled whenever the steering system is not under the influence of energy emanating from the target, that is, whenever the control represented by the term

$$\frac{d\theta_T}{dt}$$

is absent.

Homing course steering, as is clear from Equation 2, supra, normally involves no correction for differences between the bomb course angle and the relative target bearing angle due to wind or other factors. Further, such steering may not be satisfactory when the bomb is in proximity to the target if the bomb itself is not highly maneuverable. However, one advantage of such steering is that it allows some leeway in the limitation on the bearing information requisite for effective steering, particularly when the bomb is at some distance from the target.

Collision course steering, as is apparent from the discussion hereinabove and from Equation 1, provides correction for differences between the bomb heading and the actual course. However, at fairly large distances between bomb and target, rather stringent requirements are placed upon the accuracy of the rate of change of bearing information requisite for accurate steering. For example, if the bomb is to commence its attack, i. e., to be steered in accordance with energy emanating from the target, at a distance of 2 miles from the target, and the latter has a speed of the order of 40 miles per hour in the direction normal to the line of attack, the angular rate of change of target bearing is only of the order of 0.3 degree per second. Of course, as the distance decreases this rate of change increases and for relatively small distances the accuracy requirements on bearing information requisite for satisfactory steering are considerably less stringent than for greater distances. Thus, each type of steering, i. e., collision course and homing course, has certain advantages and also certain possible disadvantages from a practical standpoint.

In accordance with one feature of this invention, a steering system is so constructed and arranged that it realizes the advantages of both collision course and homing course steering without involving the disadvantages of the two, whereby increased accuracy of bomb trajectory for given bomb maneuverability and given accuracy of target bearing information is attained. More specifically, in accordance with one feature of this invention, both collision and homing course steering are provided in such relation that for large distances between bomb and target the bomb is directed substantially along a homing course, in proximity to the target it is steered substantially along the collision course, and for intermediate distances the steering changes automatically and gradually from homing course to collision course as the bomb approaches the target.

Such a system, illustrative of one embodiment of this invention, is shown in block diagram form in Fig. 2 and comprises a detector 10 responsive to energy emanating from a target for producing a signal proportional to the relative target bearing, θ_T, a differentiator 11 energized in accordance with the output of the detector 10 for producing a signal proportional to the rate of change of relative target bearing,

$$\frac{d\theta_T}{dt}$$

and a gyroscope element 12 for producing a signal proportional to the rate of change of bomb heading,

$$\frac{d\theta_H}{dt}$$

The three signals noted are applied to a control 13 for an actuator 15 in such manner that the steering rudder 14 is deflected in one direction or the other in accordance with the polarity and amplitude of the resultant of the three signals.

The elements of the system illustrated in Fig. 2, it will be understood, are mounted appropriately on a bomb carrying an expolsive charge. The bomb itself may be, mechanically, of construction similar to aircraft provided with automatic pilots. Inasmuch as such constructions are known, in the interests of simplicity, illustration thereof has been omitted from the drawing.

A specific steering system of the configuration shown in Fig. 2 and intended to be energized in accordance with radiant heat emanating from a target is illustrated in Fig. 3. In this system, the detector comprises a mirror 16 mounted opposite a parabolic reflector 17 at the focal point of which a bolometer 18 is mounted, the bolometer being highly sensitive to infra-red radiation received thereby, whereby its resistance varies in accordance with such radiation. The mirror is oscillated at a prescribed frequency, for example 10 cycles per second, as by a motor 19, whereby the mirror repeatedly scans a field. Of course, in a bomb steering system the mirror 16 is mounted on the bomb in such manner as to scan an angular field ahead of the bomb. Infra-red radiation received by the mirror 16 is reflected to the reflector 17 and from the latter to the bolometer 18. The direction of incidence upon the reflector 17 will be dependent, as is apparent, upon the position of the mirror 16.

The bolometer 18 is included in the input circuit of an amplifier 20 together with a suitable source, such as a battery 21, and resistor 22. The amplifier 20 has a relay 23 in its output circuit and is so biased normally that the relay is released. When the field scanned by the mirror 16 is of uniform temperature throughout, the resistance of the bolometer 18 remains constant. However, if this field contains a temperature discontinuity, for example, a region of elevated temperature due to an object, such as a ship, at some point in each scanning cycle, determined by the position of the object in the field and, hence, its bearing relative to the bomb, radiant energy emanating from the object will reach the bolometer via the mirror 16 and reflector 17. Hence, the bolometer resistance is changed and signal pulses are applied to the amplifier whereby the relay 23 is caused to operate.

Associated with the mirror 16 is a potentiometer resistor 24 energized from a source, such as a battery 25, the control arm 26 of the resistor being coupled to the mirror by a coupling including a backlash introducing linkage indicated at 27. This linkage is constructed and arranged to establish the same phase relation between the signal obtained from the potentiometer 24, 25 and the motion of the mirror, as exists between the signals received by the bolometer and the operation of the relay. That is to say, the linkage introduces a lag in potentiometer signal equal to the sum of the electrical delay introduced by the bolometer and amplifier and the delay time of the relay. Thus, cophasic relation is established between the potentiometer signal and relay operation.

The potentiometer signal or voltage, it will be apparent, is proportional to the angle at which the mirror 16 is receptive to radiation. This voltage is applied to a condenser 28 over an obvious circuit including the armature 30 and contact 31 of the relay 23, when the relay operates. Inasmuch as the point in the scanning cycle at which the relay is operated as the result of reception of energy by the bolometer is related to the position of the mirror corresponding to that point and the potentiometer signal or voltage is a function of the position of the mirror, the voltage to which the condenser is charged when the relay operates is proportional in magnitude and related in polarity to the relative target bearing, θ_T, and hence, represents the homing course steering function, F_H.

The voltage to which the condenser 28 is charged is applied to the control grids of the amplifier devices 29 and 32. Thus, the output of the device 32 is proportional to the relative target bearing. The output of the device 29, which also is proportional to the relative target bearing, is supplied to a condenser 33 and resistor 34, both the condenser 33 and resistance 34 being small so that the voltage appearing across the resistor 34 is proportional to the time derivative of the voltage to which the condenser 28 is charged, and, hence, represents the term

$$\frac{d\theta_T}{dt}$$

in the collision course steering function. This voltage, that is, that appearing across the resistor 34, is impressed upon the input circuit of the amplifier device 35 as will appear from the description hereinafter.

The relay 23 is provided with a second armature 36 and associated contact 37 included in the energizing circuit for a second relay 38, this circuit including also a source, such as a battery 39, a resistor 40 and a condenser 41 bridged across the resistor 40 and relay winding in series. The time constant of the resistance-capacitance circuit defined by the condenser 41, resistor 40 and relay winding is made such by correlation of the parameters involved that the relay 38 remains continuously operated when the relay 23 operates momentarily on each scan, i. e., when an object, i. e., target, is present in the field scanned by the mirror 16. The relay 38 is provided with a pair of armatures 42 and 43 associated with contacts 44*a* and 45*a* and 44*b* and 45*b* respectively. The armatures 42 and 43 are connected respectively to the midpoint of a source, such as a battery 46, bridged across a potentiometer resistor 47, and the contact arm 48 of this resistor. The contact arm 48 is driven by a gyroscope 49 which is so mounted on the bomb and so constructed in ways known in the art that the amplitude of deflection of the contact arm and, hence, the signal obtained from the potentiometer 46, 47 is proportional to the rate of change of bomb heading. Thus, this signal represents the term,

$$\frac{d\theta_H}{dt}$$

in the collision course steering function.

As has been pointed out heretofore, it is advantageous that the steering control corresponding to the term

$$\frac{d\theta_H}{dt}$$

be disabled when the control corresponding to the term

$$\frac{d\theta_T}{dt}$$

is absent, i. e., when no energy from a target is received at the mirror 16. The control corresponding to the

$$\frac{d\theta_H}{dt}$$

term is of a sense opposite to that of gyroscope stabilizing control. Thus, the control due to the term noted may be disabled in effect for the purpose intended by making the sense of the control due to the gyroscope such that this control is applied as a stabilizing control when no target energy is received at the mirror. This is accomplished in the system illustrated in Fig. 3, for, as is apparent, when the relay 23 is not operating, the relay 38 is released and the signal due to the potentiometer 46, 47 is impressed upon the grid of the device 35 in the circuit traced from the grid of the device, over contact 45*a*, armature 42, to the potentiometer 46, 47 and contact arm 48, and thence to the cathode of the device 35 by way of armature 43, contact 44*b* and resistor 34, whereas when a target appears in the field scanned, the relay 38 operates as noted heretofore and the signal due to the gyroscope and associated potentiometer is then applied to the grid circuit of the device 35 closed over armature 42 and contact 44*a* and over armature 43 and contact 45*b*. That is, operation of the relay 38 effects a reversal in polarity of the signal due to the gyroscope control, as applied to the grid circuit of the device 35.

When the relay 38 is operated, the voltage applied to the grid circuit of the device 35 is proportional to the sum of

$$\frac{d\theta_T}{dt}$$

represented by the voltage across the resistor 34, and

$$\frac{d\theta_H}{dt}$$

represented by the voltage due to the potentiometer 46, 47. Thus, the output of the device 35 represents the collision course steering function.

The anodes of the devices 32 and 35 are connected directly to one another and to the anodes of other devices described hereinafter, and in circuit with a control relay 50 and source 51. The relay comprises a pair of contacts 52 and an armature 53 which may be biased, as by a spring 54, so that normally it is out of engagement with both the contacts 52. The relay 50 serves to control the direction of rotation of a reversible motor 15 having a pair of field windings 55 the energizing circuit of which includes the source 56, armature 53 and a respective contact 52. The field winding circuits are such that when the armature 53 engages one contact 52, the motor 15 will revolve in one direction and when the armature engages the other contact, the motor will revolve in the other direction. The rudder 14, which is coupled to the motor by a suitable linkage indicated by the broken line 57, is deflected, accordingly, in one direction or the other. As is apparent, which of the contacts 52 is engaged by the armature 53, and hence the direction of deflection of the rudder 14, is determined by the current supplied to the relay 50. The latter, in turn, is determined by the resultant of the several controls.

One of these controls, provided by way of the device 32, is in accordance with the homing course function; another, provided by the device 35, is in accordance with the collision course function. Neglecting, for the moment, other controls, it will be seen that when a target is within the field scanned by the mirror 16, the control signal for the relay 50 comprises homing course and collision course components. The relative strengths of the components may be adjusted by resistors 58 included in the cathode circuits for the devices 32 and 35.

As has been pointed out heretofore, for large distances between the bomb and the target, homing course steering is desirable whereas for small distances collision course steering is desirable. Thus, advantageously, the resistors 58 are made such that for conditions corresponding to such large distances, the homing course component of the control signal for the relay is large in comparison to the collision course component. As the bomb approaches the target, the rate of change of true target bearing per degree of course error increases rapidly. Thus, the collision course steering component increases automatically, relative to the homing course component, as the bomb approaches the target and, for small distances, essentially collision course steering control is realized.

In some cases, proportional steering may be desirable. This may be obtained by the introduction of another component in the control signal for the relay 50. In one construction, such component may be provided by a potentiometer including a source 59 and resistor 60 the contact arm 61 for which is coupled to the rudder 14. The potentiometer 59, 60 is included in the grid circuit of an amplifier device 62 in such manner that the output of the device is varied in the sense opposite to that of the resultant of the components, due to the devices 32 and 35, resulting in deflection of the elevator. The relative sensitivity of the follow-up control thus provided may be adjusted by a resistor 63 included in the cathode circuit of the device 62. When the signal component due to the potentiometer 59, 60 is equal to the components due to the steering controls provided by the devices 32 and 35, the rudder 14 remains in the position requisite to maintain the bomb on-course or oscillates at small amplitude about this position.

Other control components may be provided by way of of an additional amplifier device 64, the control grid circuit of which is energized in accordance with appropriate signals. For example, in a system such as described for steering the bomb horizontally, the input signals for the device 64 may be derived from a compass element so that this device effects control of the relay to maintain the bomb upon a preset course in the absence of a target in the field scanned by the mirror 16. Such compass control may be disabled, as by operation of the relay 38, when a target appears in the field noted.

Although the invention has been described thus far particularly with reference to steering a bomb in the horizontal direction, it may be embodied also in systems for steering a bomb in the vertical direction. In such case, of course, the direction of oscillation of the mirror 16 would be at right angles to the direction of scan for horizontal steering. In a vertical steering system, the additional controls provided by way of the device 64 may be such, for example, as to maintain the bomb at a preassigned altitude in the absence of a target within the field viewed or for a prescribed time after launching of the bomb, or to control the rate of climb or drive for similar conditions.

It will be understood, of course, that two systems, one for vertical and the other for horizontal steering may be utilized, the two being effective to guide the bomb in various ways dependent upon the tactical procedure desired. For example, the two systems may be so constructed and arranged that the bomb is maintained at a prescribed altitude, by a control signal obtained from the device 64 in the vertical steering system, and is steered horizontal only in accordance with energy from the target received at the mirror 16 in the horizontal system, until it is within a preassigned range of the target whereupon vertical steering is transferred from altitude control to control in accordance with target signals and thereupon both systems guide the bomb toward the target, for example, along a collision course. The transfer, in the vertical system, from altitude to target signal control may be effected by a gate or transfer element associated with the amplifier 20 and device 64 and operable to enable the amplifier 20 to disable the device 64 only when the level of signals received by the bolometer 18 is of at least a preassigned magnitude.

It will be understood also that the specific embodiment of the invention shown and described is but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. A steering system for a moving body, comprising a steering member, means responsive to radiant energy emanating from a target for producing a first signal related in sense and amplitude to the direction and rate of change, respectively, of the bearing of the target relative to the body, means for producing a second signal related in sense and amplitude to the direction and rate of change, respectively, of heading of said body, means for resolving said first and second signals into a control signal related in sense and amplitude to the algebraic sum of said first and second signals, and means for effecting actuation of said steering member controlled in accordance with said control signal.

2. A steering system in accordance with claim 1 comprising means for reversing the sense of said second signal when the target radiant energy received by said detector means is below a preassigned magnitude.

3. A steering system for a moving body, comprising a steering member, control means for effecting deflection of said steering member in one direction or the other in accordance with the polarity of a control signal applied to the control means, means responsive to radiant energy emanating from a target for producing a first signal of polarity determined by the direction, and amplitude proportional to the rate of change of bearing of the target relative to the body, means for producing a second signal of polarity determined by the direction, and of amplitude proportional to the rate of change of heading of said body, and means for resolving said first and second signals into a control signal applied to said control means and of polarity and amplitude determined by the algebraic sum of said first and second signals.

4. A steering system in accordance with claim 3 comprising means controlled by said radiant energy responsive means for reversing the polarity of said second signal when no target radiant energy is received by said responsive means.

5. A steering system for a moving body, comprising a steering member, detector means responsive to wave energy emanating from a target, means controlled by said detector means for producing a first signal related in polarity and amplitude to the bearing of the target relative to the body, means for producing a second signal related in polarity and amplitude to the bearing of said target with respect to a reference direction, means for producing a control signal of polarity and amplitude determined by the algebraic sum of said first and second signals, and means controlled in accordance with said control signal for actuating said steering member.

6. A steering system for a moving body, comprising a steering member, detector means responsive to wave energy emanating from a target, means controlled by said detector means for producing a first signal related in polarity and amplitude to the bearing of the target relative to the body, means energized in accordance with said first signal for producing a second signal proportional to the time derivative of said first signal, means for producing a third signal of polarity and amplitude determined by the rate of change of heading of said body, means for resolving said second and third signals in combination into a control signal of polarity and amplitude determined by the algebraic sum of said second and third signals, and means controlled in accordance with said control signal for actuating said steering member.

7. A steering system for a moving body, comprising a steering member, detector means responsive to wave energy emanating from a target, means controlled by said detector means for producing a first signal related in polarity and amplitude to the bearing of the target relative to the body, means energized in accordance with said first signal for producing a second signal proportional to the time derivative of said first signal, means for producing a third signal of polarity and amplitude determined by the rate of change of heading of said body, means for resolving said first, second and third signals in combination into a control signal of polarity and amplitude determined by the algebraic sum of said first, second and third signals, and means controlled in accordance with said control signal for actuating said steering member.

8. In combination, radiant energy responsive means for repeatedly scanning an angular field, means actuated in accordance with the motion of said scanning means for producing a signal of polarity and amplitude at any time determined by the position of said scanning means at that time, a condenser connected in a normally open circuit with said signal producing means, means for closing said circuit at the time in each scanning cycle at which radiant energy is received by said responsive means from a source in said field, whereby said condenser is charged to a voltage of polarity and amplitude determined by the bearing of said source relative to said responsive means, means energized in accordance with said voltage for producing a signal substantially proportional to the time derivative of said voltage, and means energized in accordance with said signal.

9. In combination, a mirror, means for oscillating said mirror, potentiometer means coupled to said mirror for producing a direct current signal of polarity and amplitude determined by the position of said mirror at any instant, a normally open utilization circuit including said potentiometer means, and means responsive to wave energy reflected from said mirror for closing said circuit whenever said mirror encounters an energy discontinuity in the field scanned thereby.

10. In combination, a mirror, means for oscillating said mirror, potentiometer means coupled to said mirror for producing a direct current signal of polarity and amplitude determined by the position of said mirror at any instant, a condenser having a normally open charging circuit including said potentiometer means, means responsive to wave energy reflected from said mirror for closing said

circuit when said mirror received wave energy from a source in the field viewed thereby, whereby said condenser is charged to a voltage of polarity and amplitude determined by the bearing of said source with respect to said mirror, means energized proportionately to said voltage for producing a signal substantially proportional to the time derivative of said voltage, and means energized in accordance with said signal.

11. In combination, a mirror, means for oscillating said mirror, potentiometer means coupled to said mirror for producing a direct current signal of polarity and amplitude determined by the position of said mirror at any instant, a condenser having a normally open charging circuit including said potentiometer means, means responsive to wave energy reflected from said mirror for closing said circuit when said mirror receives wave energy from a source in the field received thereby, whereby said condenser is charged to a voltage of polarity and amplitude determined by the bearing of said source with respect to said mirror, a first electron discharge device having an input circuit including said condenser and having an output circuit including a resistance and condenser in series and of such relative constants that the potential across said resistance is substantially the time derivative of the input signal to said device, a second electron discharge device having an input circuit including said resistance, and operating means connected to the output circuit of said second device.

12. A steering system for a moving body, comprising a steering member, control means for effecting deflection of said steering member in accordance with the polarity of the energizing signal applied to said means, an energizing circuit for said control means, including a pair of electron discharge devices the output circuits of which are in parallel relation, means responsive to radiant energy emanating from a target for producing a first signal of polarity and amplitude determined by the bearing of said target relative to the body, means for controlling the output of one of said devices in accordance with said first signal, means energized in accordance with said output for producing a second signal of amplitude determined by the rate of charge of said bearing, an input circuit for the other of said devices, means for impressing said second signal upon said input circuit, and means for impressing upon said input circuit a third signal of polarity and amplitude determined by the direction and rate of change respectively of the heading of said body.

13. A steering system in accordance with claim 12 comprising means for reversing the polarity of said third signal when the energy received by said radiant energy responsive means is of less than a preassigned magnitude.

14. A steering system in accordance with claim 12 wherein said radiant energy responsive means includes a mirror, means for oscillating said mirror, means actuated in accordance with motion of said mirror for producing a direct current signal of polarity and amplitude at any time determined by the position of said mirror at that time, a condenser connected in a normally open circuit with said direct current signal producing means, and means responsive to energy reflected from said mirror for closing said normally open circuit when said mirror receives energy from the target.

No references cited.