

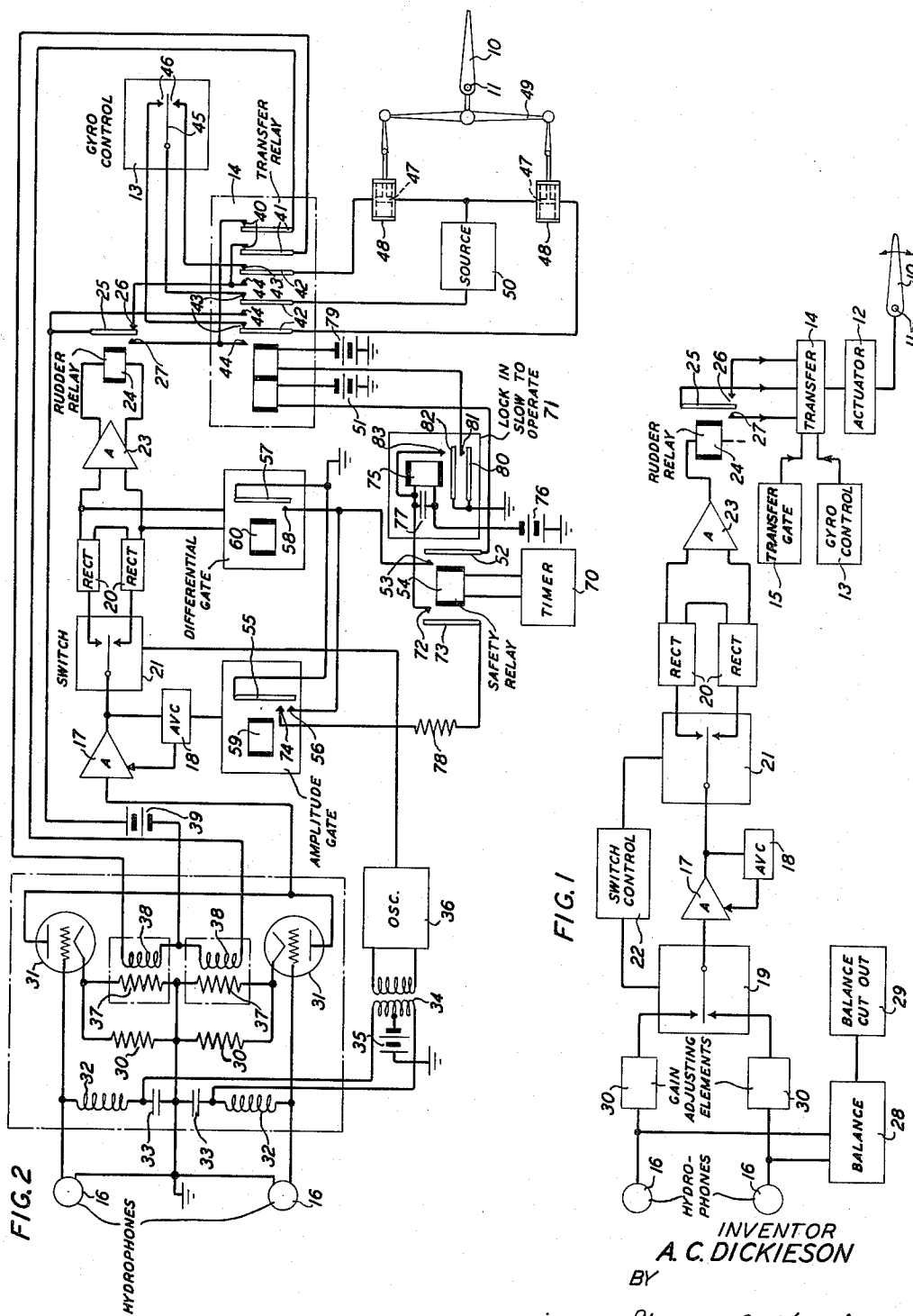
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TORPEDO STEERING SYSTEM

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TORPEDO STEERING SYSTEM

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This invention relates to control circuits and more particularly to steering systems for sonically guided torpedoes such as disclosed in the application Serial No. 545,835 filed July 20, 1944, of Alton C. Dickieson and Serial No. 549,003, filed August 11, 1944, of Alphons V. Wurmser.

In torpedo steering systems of the type disclosed in the above-identified applications, the rudder is controlled by a gyroscope for a period following launching of the torpedo, to maintain the torpedo on a preset course and then is transferred to control in accordance with submarine signals such as noises emanating from the target, e.g. ship, whereby the torpedo is guided toward the target by such signals. The target signal control of the rudder is effected by a system of the general type disclosed in the application Serial No. 491,795, filed June 22, 1943, of Donald D. Robertson and comprising a pair of signal channels, a pair of hydrophones mounted on opposite sides of the torpedo and each constituting the input element for a respective channel, means for combining the outputs of the channels in difference relation and a control element actuated in accordance with the polarity of the resultant signal for causing deflection of the rudder in one direction or the other.

There is the possibility that the torpedo may miss the target and pass beyond it. The target signal field intensity decreases with increasing distance from the target so that in instances where the torpedo fails to strike the target, it may pass outside the effective target signal field. Also, as will be appreciated, the torpedo may be traveling in such direction when it passes beyond the target that the difference in the signal amplitudes at the two hydrophones is very small. Such condition is mostly likely to occur in constructions wherein the hydrophones are directional in the forward direction. Hence, the steering system may not be controlled in accordance with target signals and thus, the torpedo may fail to reattack the target.

One object of this invention is to control a sonically guided torpedo so that in the event it misses the target it will be steered upon a course likely to bring it within the effective signal field of the target and to bring it under control of the target signals.

In accordance with one feature of this invention, means are provided for unbalancing the two signal channels to a prescribed degree sufficient to produce substantial deflection of the rudder in one direction in the absence of other controls. Thus, if the torpedo misses the target and is in such position relative thereto that the target signals are not effective to control the steering system, because of the unbalance between the channels the rudder will be deflected to turn the torpedo about and bring it within the effective target signal field.

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 largely in block form of a torpedo steering system illustrative of one embodiment of this invention; and

FIG. 2 is a circuit diagram partly in functional schematic form, showing details of a typical system of the construction illustrated in FIG. 1.

Referring now to the drawing, the steering system

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illustrated in FIG. 1 comprises a rudder 10 pivoted at 11 and deflectable in opposite directions by a suitable actuator 12. The actuator is adapted to be controlled by one or the other of a gyroscope control element 13 or a signal actuated system both of which are arranged for operative association with the actuator by a transfer element 14 which is controlled by a transfer gate 15. The gyroscope control 13 normally is operatively associated with the actuator 12 and the signal actuated system normally is dissociated therefrom. Thus, when the torpedo is launched and until the transfer element 14 operates, the rudder is gyroscope controlled and the torpedo is maintained on a preset course. When the transfer element 14 operates, the signal actuated system is associated operatively with the actuator 12 and the gyroscope control 13 is dissociated therefrom so that the rudder is placed under control of the signal actuated system.

This system may be of the general construction disclosed in the aforementioned application of Donald D. Robertson and comprises a pair of similar hydrophones 16 which are mounted on opposite sides of the torpedo, for example, on the port and starboard sides of the head or nose portion thereof, and may be forwardly pointing and have maximum sensitivity to submarine signal waves incident normal to the faces thereof. The hydrophones are arranged, in a manner described in detail hereinafter, to be connected in alternation to an amplifier 17, provided with automatic gain control 18, the alternate connection being effected by a switch 19. The output of the amplifier 17 is supplied to a pair of rectifiers 20 by way of a switch 21 which is actuated in synchronism with the switch 19 by a switch control 22.

It will be seen, then, that the signal actuated system comprises two similar signal channels each of which includes the amplifier 17, a hydrophone 16 and the respective rectifier 20.

The outputs of the two rectifiers, each output being proportional to the signal amplitude at the respective hydrophone, are connected in difference relation and the resultant signal is impressed upon the input circuit of a direct current amplifier 23 which normally is biased at cut-off and which controls a rudder relay 24 in accordance with the polarity of the resultant signal noted. The relay 24 has an armature 25 which engages a contact 26 when the resultant signal is of the polarity to increase the amplifier bias, and has a second contact 27 which is engaged by the armature 25 when the resultant signal is of the opposite polarity. The armature 25 and contacts 26 and 27 are adapted to be connected to the actuator 12 over the transfer element 14 so that when the signal actuated system is associated operatively with the actuator 12 by the transfer element 14, the rudder 10 is deflected in accordance with the relative outputs of the two signal channels, specifically in accordance with the polarity of the resultant signal aforementioned. As will be apparent, when the torpedo is within the effective signal field of the target the resultant signal is related to the relative signal intensities at the two hydrophones and the polarity of this signal is determined by the direction of the target with respect to the torpedo, so that the rudder is deflected to guide the torpedo to the target.

As pointed out in the above-mentioned application of Alton C. Dickieson, it is highly desirable that at the time the rudder is transferred from gyroscope to signal control, the two channels of the signal actuated system be in substantial balance, that is, that in the absence of signals at the hydrophones the resultant signal obtained from the rectifiers 20 in combination be substantially zero. Such condition is produced by a balance element 28, which may be of the forms described in detail in the Dickieson and Wurmser applications noted hereinbefore, associated with the two channels and provided with a cut-out 29. As

pointed out in those applications, the balance 28 adjusts the relative gains of the two channels so that at the time the rudder is transferred from gyroscope to signal control, dissymmetries between the two channels are compensated for and these channels are substantially balanced on torpedo self-noise and random submarine noise.

Briefly, the operation of the system as described thus far is as follows: When the torpedo is launched it proceeds upon a preset course under control of the gyroscope control 13 and the two signal channels are adjusted by the balance element 28. At some time after launching, determined, for example, by a pair of controls one of which fixes the time sufficiently after the launching to permit the torpedo to travel beyond the effective signal field of the launching vessel and the other of which is actuated in accordance with a parameter of the signals at the hydrophones, such as the signal intensity or the difference in signal amplitude at the two hydrophones, or both, the cut-out 29 operates to disable the balance element 28 and the gate 15 operates the transfer 14 to shift the rudder from gyroscope to signal control. The channels are substantially balanced at the time the transfer occurs and thereafter the torpedo is guided to the target in accordance with signals emanating therefrom.

As has been mentioned hereinabove, the possibility exists that the torpedo may miss the target and pass to such position relative thereto that is not subjected to control in accordance with the target signals and, hence, will not re-attack the target. In accordance with one feature of this invention, the signal actuated steering system is so constructed that in the event the torpedo misses the target, the rudder will be deflected to cause the torpedo to turn about and again attack the target. Specifically, in one illustrative embodiment of the invention, sensitivity or gain adjusting elements 30 are included in the two signal channels to create a preassigned degree of unbalance between the channels sufficient to cause full deflection of the rudder in one direction.

While the torpedo is under gyroscope control the balance element 28 compensates for this unbalance as well as for other dissymmetries between the channels so that the resultant signal obtained from the rectifiers 20 is substantially zero. When the torpedo comes under control of the target signals, the unbalance noted is overcome due to the manner of operation of the signal actuated system. Now, if the torpedo misses the target and passes substantially beyond it, the channels tend to return to their initial unbalanced condition due to the elements 30 whereby full rudder is produced and the torpedo is caused to follow a circular path. As will be apparent, when the torpedo is thus turned, it will be faced toward the target and, therefore, the conditions are good for return of the steering system to control in accordance with the target signals, whereby the torpedo will be guided to reattack the target.

It will be understood, of course, that advantageously the degree of unbalance introduced by the elements 30 is such as to just result in substantially full rudder in the absence of target signals whereby the effect of the unbalance upon the operation of the signal actuated system in accordance with target signals and its effect upon the range of this system upon reattack are made small; that is to say, if, for example, full rudder, e.g. 20 degrees, is produced by one decibel difference in signal amplitudes at the two hydrophones, the unbalance introduced by the elements 30 advantageously should be no greater than one decibel.

Details of a typical steering system constructed in accordance with the invention are illustrated in FIG. 2. As shown in this figure, each of the hydrophones 16 is connected to the input circuit of a respective electron discharge device 31, the two devices being similar and having their anodes connected in common to the amplifier 17. Associated with each hydrophone is an inductance 32 and a condenser 33, advantageously correlated with the hydrophone to resonate the combination at a prescribed fre-

quency, the two combinations being substantially identical. Bridged across the condensers 33 is the secondary winding 34 of a transformer, the midpoint of the winding 34 being connected to ground by way of a source 35 which serves to bias the control electrodes of the devices 31 beyond cut-off. The primary winding of the transformer is energized from an alternating current source 36, such as an electronic oscillator, of such construction as to impress upon the input circuits of the devices 31 a potential sufficient to overcome the blocking bias due to the source 35, whereby the two devices 31 are rendered conductive in alternation. As indicated in the drawing, the source 36 serves also to control the switch 21 whereby the rectifiers 20 are connected to the output of the amplifier 17 alternately and in synchronism with the switching of the two devices 31.

The input circuit for each device 31 includes a respective resistor 30, the two resistors 30 being of different magnitudes to establish the desired prescribed unbalance between the two signal channels as described heretofore. Each resistor 30 has in parallel therewith a second resistor 37, the resistors 37 having a high temperature coefficient of resistance and being large in comparison to the resistors 30. Thermally coupled to each of the resistors 37 is a respective heater element 38, the two elements having one end connected in common to the armature 25 of the rudder relay 24 by way of a source 39 and each having its other end connected to a respective one of the contacts 26 or 27 of this relay over the respective contact 40 and armature 41 of the transfer relay 14.

The transfer relay 14 is provided also with the armatures 42 and associated transfer contacts 43 and 44, the armatures being normally in engagement with the contacts 43 as shown. The armature 25 and contacts 26 and 27 of the rudder relay are each connected to the respective contact 44.

The gyro control 13 may be of known construction and, therefore, need not be described in detail here. Suffice it to say that it comprises an armature 45 and transfer contacts 46, the armature 45 being actuated to engage one or the other of the contacts 46 in accordance with the direction of departure of the torpedo from the course for which the gyroscope is set. As shown, the armature and contacts of the gyroscope control are connected to the contacts 43 of the transfer relay.

The rudder 10 is coupled to the armatures 47 of solenoids 48 by a suitable linkage 49, the solenoids having one end connected in common to a source 50 and thence to one of the armatures 42 and each having its other end connected to a respective armature 42. As is apparent, the rudder 10 will be deflected in one direction or the other in accordance with which of the contacts 46 is engaged by the armature 45, when the gyroscope control is associated with the solenoid circuits, and in accordance with which of the contacts 26 or 27 is engaged by the armature 25, when the signal actuated system is associated with the solenoids.

As has been pointed out heretofore, operation of the transfer relay 14 may be determined by two controls. Specifically, the energizing circuit for the transfer relay comprises, in one form, a source 51 the armature and contacts 52 and 53 respectively of a safety relay 54 and the parallel connected armatures 55 and 57 and contacts 56 and 58 of relays 59 and 60 respectively. The safety relay 54 is controlled by a timer 70 to close its contact at a time sufficiently subsequent to the launching of the torpedo to enable the latter to travel beyond the effective signal field of the launching vessel. The relay 59 is controlled in accordance with the potential of the automatic gain control 18 and is designed to close its contact only when this potential is of at least a preassigned magnitude. Thus, this relay is an amplitude gate and will operate only when the signal level at the hydrophones is of at least a preassigned amplitude. The relay 60, which constitutes a differential gate, is energized in accordance with

the difference between the outputs of the rectifiers 20 and is so designed that it will operate to close its contacts only when this difference is of at least a prescribed magnitude. Advantageously, the amplitude gate relay 59 is made less sensitive than the differential gate relay 60. As will be apparent, operation of the safety relay 54 and one or the other of the gate relays 59 and 60 is requisite for energization of the transfer relay 14 to shift the rudder from gyroscope to signal control.

The transfer relay 14 may be provided with a lock in element 71, the energizing circuit for which normally is open at the contact 72 and armature 73 of the safety relay 54 and which, when the relay 54 operates, is connected to the contact 74 of the amplitude gate relay 59. The lock-in element may comprise a relay 75 energized from a source 76, such as a battery, over a circuit which includes a condenser 77 and a resistor 78 correlated to delay operation of the relay 75 for a preassigned time after completion of this circuit by operation of the relay 54 and amplitude gate relay 59. The lock-in circuit for the transfer relay 14 includes a source 79 and the armature 80 and contact 81 of the relay 75. The latter relay also has a lock-in circuit which is closed at armature 82 and contact 83 through the source 76.

The operation of the steering system illustrated in FIG. 2 is as follows: When the torpedo is launched, the circuit is in the condition shown in the drawing so that the gyroscope control 13 is associated with the solenoids 48 over the armature 42 and contacts 43 of the transfer relay 14 and the energizing circuits for the heater elements 38 are under control of the rudder relay 24 over the armatures 41 and contacts 40 of the transfer relay. As the torpedo proceeds away from the launching vessel, the rudder relay 24 is operated in accordance with the signals received by the hydrophones 16 and the armature 25 is actuated to engage one or the other of the contacts 26 or 27 in accordance with the effective direction of such signals with respect to the longitudinal axis of the torpedo. While the torpedo is in the vicinity of the launching vessel and within the effective signal field thereof, the signals received by the hydrophones 16 are composed of signals emanating from the launching vessel, signals due to torpedo self-noise and such random submarine signals as may be present. As the torpedo moves away from the launching vessel, the level of the signals due to this vessel decreases and, as will be apparent, at a substantial distance from this vessel, the signals received by the hydrophones 16 will be composed almost entirely of signals due to torpedo self-noise and such random submarine signals as may be present. As has been pointed out heretofore, the rudder relay 24 is operated in accordance with the difference in the output of the two signal channels so that, as will be apparent, the two heater elements 38 are heated relatively in accordance with the magnitude of the departure from equality between the output of the two channels. The resistors 37, thus, will be varied each in accordance with the degree to which it is heated by the associated heater element 38 until the signal actuated system is in such condition that the armature 25 engages the contacts 26 and 27 for substantially equal periods. Hence, after the torpedo has traveled a substantial distance from the launching vessel, the two signal channels will be substantially balanced on torpedo self-noise and such random submarine noise as may be present and this balanced condition will be realized despite the dissymmetry between the two channels due to the inequality of the resistors 30.

At a predetermined time sufficient, as noted heretofore, to allow the torpedo to reach a position beyond the effective signal field of the launching vessel, the timer 70 operates to close its contacts whereby the energizing circuit for the transfer relay is conditioned for control by the amplitude and differential gate relays 59 and 60, respectively. Until one or the other, or both, of the gate relays operates, the rudder remains under control of

the gyroscope control 13. Now when the torpedo enters the signal field of the target, first the differential gate relay 60 operates whereby the energizing circuit for the transfer relay 14 is closed and the armatures 42 are moved out of engagement with the respective contacts 43 and into engagement with the respective contacts 44 and the armatures 41 are disengaged from the contacts 40. Hence, as will be seen, the energizing circuits for the heater elements 38 are opened and the rudder is transferred from control by the gyroscope 13 to control in accordance with the operation of the rudder relay 24. The differential gate relay may alternately operate and release as the torpedo oscillates about the direct course to the target.

When the torpedo approaches close enough to the target so that the target signal level at the hydrophone 16 is sufficient to result in operation of the amplitude gate relay 59, this relay operates to close its contacts and the rudder is committed to target signal control. The thermal characteristics of the resistors 37 and associated heater element 38 are made such that by the time the torpedo reaches the immediate vicinity of the target they have cooled to a substantial extent. If the torpedo should miss the target and pass a substantial distance therebeyond, because of the inequality of the resistors 30, the two signal channels are sharply unbalanced assuming, of course, that the torpedo is at such position that the target signal level at the hydrophones is insufficient to actuate the signal actuated system in accordance therewith and thus control the rudder. Because of this unbalance, which, as noted heretofore, is of sufficient amplitude to result in full rudder deflection, the torpedo is caused to turn about sharply whereby it follows a circular path and thus at some point in this path is directed toward the target signal field. Thus, it is placed in such position that conditions are good for return of the rudder to control in accordance with the target signals, and to reattack the target.

It will be noted that the heating period for the heater elements 38 is determined by the operation of the transfer relay 14 so that the energizing circuit for the heaters 38 will not be disabled until the torpedo has entered the signal field of target. Thus, the two signal channels are balanced on torpedo self-noise and such random submarine noise as may be present at the time the rudder is transferred from control by the gyroscope to control in accordance with the target signals, and also for an appreciable time thereafter, dependent upon the cooling rate of the heaters and the associated resistors 37. The cooling interval for the heater elements 38 and associated resistors 37 is substantially equal to the period of the attack and, hence, is substantially the same for various ranges of attack, that is, distances between the launching vessel and the target. Thus the characteristics of the heater elements 38 and resistors 37 may be made such in relation to the period of first attack that at the time the torpedo reaches the immediate vicinity of the target, the resistors 37 have cooled sufficiently to allow the resistors 30 to establish a substantial unbalance between the two signal channels.

Although a specific embodiment of the invention has been shown and described, it will be understood that it 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 torpedo, comprising a rudder, actuating means for said rudder, gyroscope means for controlling said actuating means and normally associated therewith, signal actuated means for controlling said actuating means and normally dissociated therefrom, said signal actuated means comprising a pair of signal translating devices mounted on opposite sides of the torpedo, a pair of similar signal channels each of which includes a respective translating device as an input element, means for combining the outputs of said channels in difference

relation to produce a control signal and means for controlling said actuating means in accordance with said control signal, transfer means for associating said signal actuated means with said actuating means and dissociating said gyroscope means therefrom at a time subsequent to the launching of the torpedo, means normally associated with said channels for establishing substantial balance between said channels prior to operation of said transfer means, means for disabling said balance establishing means at a time subsequent to launching of the torpedo, and means permanently associated with said signal actuated means for establishing a normal unbalance of preassigned magnitude between said channels.

2. A steering system in accordance with claim 1 wherein said unbalance establishing means comprises unequal impedance elements each included in a respective signal channel.

3. A steering system in accordance with claim 1 wherein said unbalance establishing means comprises a pair of unequal resistors each of which is included in a respective signal channel at the input end thereof.

4. A steering system for a torpedo, comprising a rudder, actuating means for said rudder, gyroscope means for controlling said actuating means and normally associated therewith, signal actuated means for controlling said actuating means and normally dissociated therefrom, said signal actuated means comprising a pair of signal translating devices mounted on opposite sides of the torpedo, a pair of similar signal channels each of which includes a respective translating device as an input element, means for combining the outputs of said channels in difference relation to produce a control signal and means for controlling said actuating means in accordance with said control signal, each of said channels including a resistor at the input end thereof and having a high temperature coefficient, individual heater means for said resistors, individual energizing circuits for said heater means, means for closing one or the other of said energizing circuits in accordance with the polarity of said control signal, transfer means for associating said signal actuated means with said actuating means and dissociating said gyroscope means therefrom, means for disabling said energizing circuits, and gate means for operating said transfer and disabling means simultaneously subsequent to launching of the torpedo.

5. A steering system in accordance with claim 4 wherein said gate means comprises a relay and means for controlling said relay in accordance with a parameter of the signals received by said translating devices.

6. A steering system in accordance with claim 4 wherein said gate means comprises a relay and means for operating said relay only when the signal level at said translating devices is of at least a preassigned magnitude.

7. A control circuit comprising a pair of similar signal channels having signal responsive input elements exposed to the same signal field and positioned so that the relative response thereof is determined by the direction relative thereto of the signals received thereby, means for combining the outputs of said channels in difference relation to produce a resultant signal, control means

associated with said channels to be actuated in accordance with said resultant signal, operating means controlled by said control means and normally dissociated therefrom, a first sensitivity adjustment means included in said channels for establishing a normal unbalance of preassigned magnitude between said channels, a second adjustment means normally associated with said control means and controlled thereby for establishing substantial balance between said channels, and means for associating said operating means with said control means and dissociating said second adjustment means from said control means.

8. A steering system for a moving body comprising a rudder, signal responsive means for controlling said rudder and normally dissociated therefrom, said signal responsive means comprising a pair of similar signal channels, a pair of signal translating devices mounted on opposite sides of the body and each serving as the input element for a respective channel, means for combining the outputs of said channels in difference relation to produce a control signal and means for controlling said rudder in accordance with said control signal, gyroscope means normally associated with said rudder for controlling it to maintain the body on a preset course, means for associating said signal responsive means with said rudder and dissociating said gyroscope means therefrom, means for adjusting said channels in accordance with signals received by said devices while said gyroscope means is associated with said rudder to establish substantial balance between said channels, and means permanently included in said channels for establishing a normal unbalance of prescribed magnitude therebetween.

9. A steering system for a moving body, comprising a rudder, signal responsive means for controlling said rudder in accordance with signals emanating from a target to guide the body to the target, said signal responsive means being normally dissociated from said rudder and comprising a pair of signal translating devices, a resolving circuit energized by said devices for converting the outputs of said devices in combination into a control signal related in polarity to the relative amplitude of the outputs of said devices, and means for actuating said rudder in accordance with the polarity of said control signal, control means normally associated with said rudder for maintaining the body on a preset course, transfer means for associating said signal responsive means with said rudder and dissociating said control means therefrom when the body comes within a preassigned range of the target, means for adjusting said signal responsive means in accordance with said control signal while said control means is associated with said rudder to adjust said control signal to substantially zero, and means permanently associated with said signal translating devices for establishing an unbalance of prescribed magnitude between the outputs of said devices as applied to said resolving circuit.

No references cited.