Aug. 11, 1970 G. M. HOLLEY, JR 3,524,187

RADIO DIRECTIONAL CONTROL SYSTEM

Filed May 17, 1968

FIG. 1

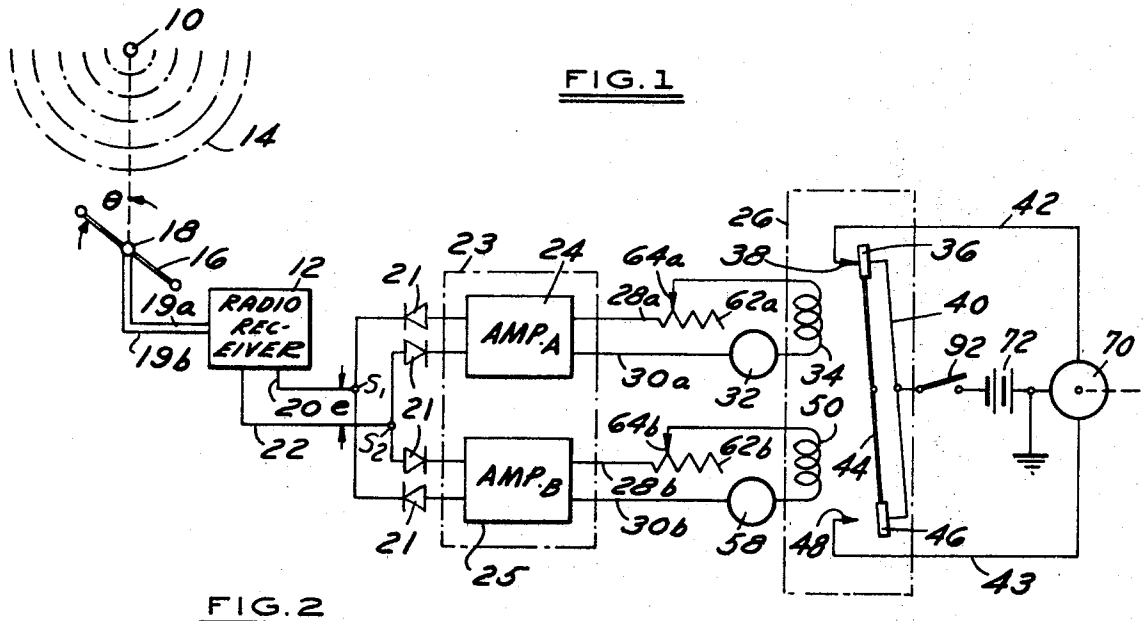


FIG. 2

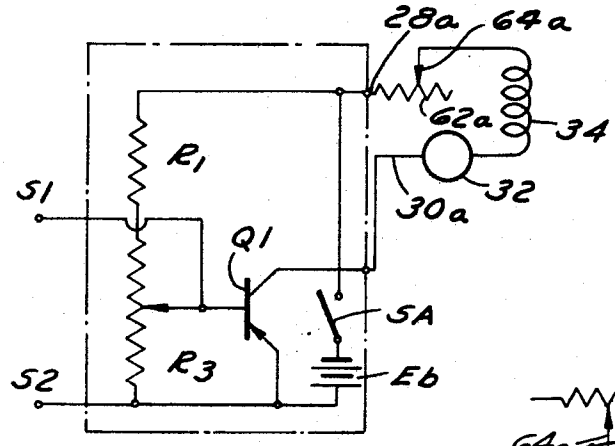


FIG. 3

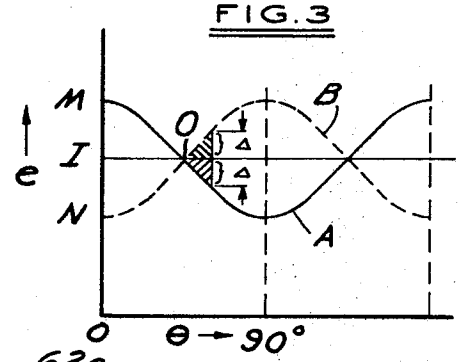


FIG. 4

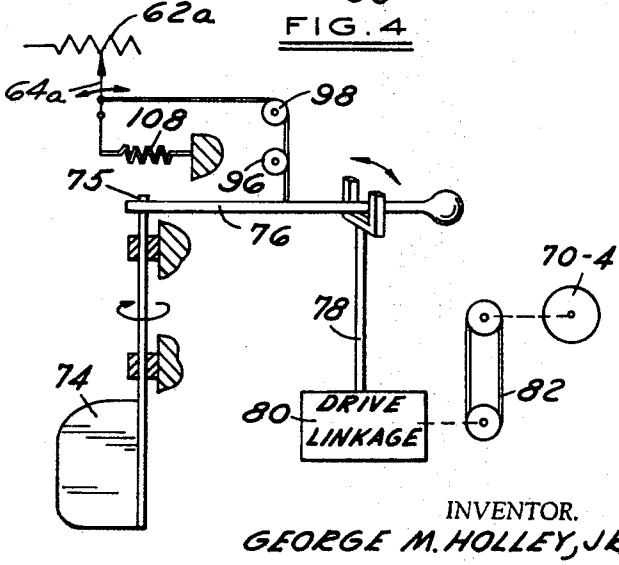
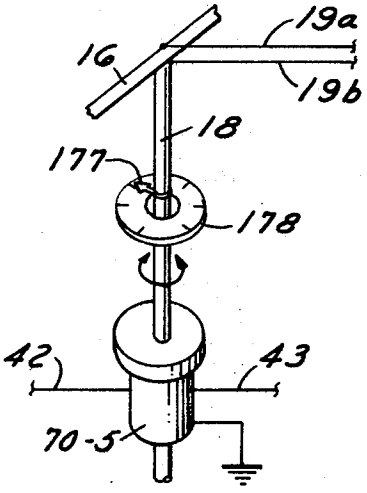


FIG. 5



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RADIO DIRECTIONAL CONTROL SYSTEM

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U.S. Cl. 343—117 13 Claims

ABSTRACT OF THE DISCLOSURE

This disclosure relates to a radio directional control system having particular utility for marine vessel navigation applications and utilizing a directional antenna and radio receiver, which has an output signal characteristic that varies in accordance with the angular or rotated position of the antenna relative to a distant radio transmitter. The system includes a reversible motor for positioning a mechanism used in navigating the vessel and compares the output of the receiver against a derived reference signal to actuate the motor in one direction or the other in accordance with the relative intensities of the signals.

BACKGROUND OF THE INVENTION

This invention relates to a radio directional control system for automatically positioning a mechanism used in navigating a craft, and, more particularly, to a control system specially suited to automatic piloting, direction finding, and position plotting applications.

The invention has for its object to provide a simple and inexpensive radio directional control system and seeks to improve and to apply control apparatus of the character disclosed in my copending application U. S. Ser. No. 639,090, filed May 17, 1967, now Pat. No. 3,419,866, to applications of the above and a related character.

Another object is to provide a control system of the stated character that exhibits a rapid and fast acting response therefrom for variations in the output characteristic of the receiver due to angular deviation of the position of the antenna from a predetermined setting thereof relative to the transmitter.

Another object is to provide a control system of the stated character that exhibits a rapid and fast acting response therefrom for variations in the output characteristic of the receiver due to angular deviation of the position of the antenna relative to the transmitter.

SUMMARY OF THE INVENTION

In general, the radio directional control system disclosed herein comprises a directional antenna connected to a radio receiver having an output circuit whose output characteristic varies with the angular position of the antenna with respect to a distant transmitter. The output of the receiver is furnished to a signal translating device comprised of a pair of signal amplifier devices providing inversely varying outputs therefrom. The outputs of the amplifiers are initially adjusted to equality and applied to the respective input sections of an amplitude comparison device which produces a resultant electrical output therefrom to cause a reversible motor to be actuated in one direction or the other depending upon the relative intensities of the output signals from the amplifiers.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic electric circuit diagram of a radio directional control system in accordance with the present invention;

FIG. 2 is a schematic electric circuit diagram of a form of amplifier employed in the control system of FIG. 1;

FIG. 3 is a graphical representation of signal variations with antenna attitude as developed in the control system of FIG. 1;

FIG. 4 illustrates the application of the radio directional control system to an autopilot apparatus for steering of a craft or vessel; and

FIG. 5 illustrates the application of the radio directional control system to an automatic radio direction finding apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 illustrates my radio directional control system provided on a craft, vessel or vehicle navigating in the vicinity of a distant radio transmitter **10** and comprises a radio receiver **12** having a directional antenna **16**, an inversely operating signal translating device **23** providing a pair of inversely or oppositely varying output signals therefrom to an amplitude comparator device **26** controlling the direction of rotation of a reversible motor **70**.

The directional antenna **16** is a loop or rod antenna, mounted on a mast **18** and is shown positioned at an angle θ relative to the direction of the wave front of the propagated wave **14** from the transmitter **10**. The antenna induces a voltage appearing between the conductor leads **19***a* and **19***b* thereof connected to the input of the receiver **12** and supplies a voltage signal thereto that varies in amplitude in accordance with the rotated or angular position of the antenna relative to the transmitter. The receiver may be of a conventional superheterodyne variety for reception of amplitude modulated carrier waves and provides an amplifier output voltage, as from the second detector section thereof, that rises and falls in accordance with the rotated or angular position of the antenna relative to the transmitter.

The output from the receiver is supplied over lines **20**, **22**, also labelled, S1, S2 to the signal translating device **23**, which, as illustrated herein, comprises a pair of amplifiers **24** and **25** of which the connections S1 and S2 are connected to the input terminals of amplifier **25** with a polarity reversed to or in the opposite manner to their connection to the input of amplifier **24**. Diodes **21** may be provided in the inputs to the amplifiers for isolation of the amplifiers, which are oppositely driven to supply correspondingly inversely varying signal outputs from the output sections respectively thereof constituting separate channels A and B of the control system of the present invention.

Each of the output channels A and B extends from the output of its corresponding amplifier supplied over conductors **28***a*, **28***b* and **30***a*, **30***b* through an adjustable potentiometer as **62***a*, **62***b* and a current indicating instrument as **32**, **58**, to a respective one of the two input sections of the comparator device **26**. The comparator comprises a polarized hunting relay having a pair of relay operating coils **34** and **50**, which selectively actuate or control the positioning of a centrally pivotable armature element **44** having a pair of contacts **36** and **46** thereon for selective engagement with a corresponding one of a pair of stationary contacts **38** and **48**. Contacts **38** and **48** are connected over conductors **42** and **43** to supply current over separate circuits from battery source **72** and through switch **92** to the reversible motor **70**, shown as a 3 terminal motor. For a 2 terminal motor intervening reversing means could be employed to reverse the connections for the direction of current through or the field of the motor.

The energization and direction of rotation of the motor **70** is thus controlled in accordance with the engagement of contacts **36**, **38** or **46**, **48**, respectively in response to the relative intensities of the signal currents in the relay coils **34** and **50**. When the currents in the relay coils are

equal, both sets of contacts **36**, **38** and **46**, **48** are open, the output of the comparator being effectively zero and the system is balanced or in equilibrium.

The amplifiers **24** and **25** may be of simple conventional form shown in the schematic circuit diagram of FIG. 2 comprising a simple PNP single stage transistor amplifier connected in a common emitter configuration. The resistor **R1** and adjustable resistor **R3** serve to adjust the bias on the base of transistor **Q1** relative to its emitter connected to the positive side of the battery source *Eb*. The collector is connected through the meter **32**, relay coil **34** and potentiometer **62***a*, to the negative side of the supply source *Eb* through switch SA. With switch SA closed, an increase in negative bias by adjusting the setting of the variable arm of resistor R3 toward resistor R1, will increase the conductivity of the amplifier, resulting in increasing the level of the current flowing through the meter **32**.

With a fixed setting of resistor R3, if the signal from the receiver is introduced at S1 and S2, then, as the signal current applied at S1 and S2 varies, so the current at **32** varies. If S1 is negative and S2 is positive, then an increase in the signal current increases the output current; if on the other hand, S1 is positive and S2 is negative, then an increase in the signal current decreases the current output proportionately.

In the embodiment, illustrated amplifier **25** is similar to amplifier A except that the input connections S1 and S2 thereto are reversed, as previously stated from the connections to amplifier A. In consequence, as the input signal across or between S1 and S2 increases, in a positive direction, for example, the output current of amplifier A will decrease, while that of amplifier B will increase. A decrease in signal current will increase the output of amplifier **24** and will decrease that from amplifier **25**. The amplifiers are thus inversely driven and operated, as in the manner of a push-pull amplifier, for example. Since it is the inversely varying relationships of the signals in the respective channels of the control system that is of importance, other connections, arrangements and compositions of single and/or compound stage amplifiers for accomplishing such inverse operation could be employed.

The manner in which the amplitude of the signal appearing between the terminals S1, S2 of the receiver varies with respect to the angular position of the antenna **16** relative to the transmitter **10** corresponds to that shown at B in FIG. 3, which is a chart of current versus the mechanical angular position or rotation of the antenna **16**. FIG. 3 also represents by curve A the signal output from amplifier **24**, while the dashed and dotted curve B represents the output from amplifier **25**, when each amplifier is adjusted to produce the same amplification or output voltage swing therefrom. In both cases, the curves vary in a harmonic manner with curve A varying from a maximum to a minimum condition and curve B from a minimum to a maximum condition as the antenna is rotated from zero to 90° and integral multiples of 90° or of $\pi/2$ radians. The curves are of opposite phase relationship and execute a complete 360° cycle of electrical variation from a minimum to maximum and back to a minimum condition in 180° of mechanical rotation of the antenna.

It will be noted that any variation in antenna angle θ produces an equal but oppositely directed effect on the output signals from the amplifiers, resulting in a net difference between the output currents that is always equal to twice the change Δ produced in either amplifier alone. This consideration and the fact that the curves A and B converge at their intersection at point O at an angle of 90° assures high system sensitivity even for slight deviations of antenna angle, and a faster attack and response that can otherwise be obtained from attempting to sense a change in the output of a single amplifier or in the receiver output signal alone.

In the case of the autopilot application illustrated in FIG. 4 of the radio directional control system of FIG. 1, the antenna **16** is positioned at a non-null position intermediate its minimum and maximum output signal producing conditions. This position corresponds to point O of the curves of FIG. 3, representing an angle θ of 45° relative to the direction of the wave front or transmitted beam. Should the craft deviate off course in one direction, the signal output will increase, and should it deviate in the other direction, the received signal current will decrease, as indicated by the curve B, for example.

A suitable drive motor **70–4**, corresponding to motor **70** of FIG. 1, is shown schematically connected to the rudder **74** of the craft through suitable mechanism, as a chain and sprocket drive transmission **82**, to a drive linkage **80** that swings a yoke-shaped rod **78**. Rod **78** in turn swings arm **76**, which is pivoted at **75** and is connected to the rudder **74** of the craft. A suitable manually or electrically disengageable clutch, not shown, ought preferably to be included in the mechanism, as in the drive linkage **80** for example, to permit normal steering of the craft when the vessel is not under autopilot control.

With the antenna positioned at or near the aforesaid angle relative to the transmitter station, the equilibrium condition is established with the operator steering or holding the vessel on a desired course and adjusting the potentiometers **62***a* and **62***b* in channels A and B to produce equal output current indications therefrom and to supply signals of equal intensity to the relay coils **34** and **50**. After equilibrium is established, the aforesaid clutch is engaged, and the operator may then leave the steering of the vessel unattended for a period of time depending upon its speed, distance from the transmitter and the direction of the course of the vessel. The operator is thus relieved of steering, and the vessel or craft is steered on autopilot.

Should the vessel deviate in one direction off course and thereby change the attitude of the directional antenna to the transmitter, the output of one amplifier or channel will increase, while that of the other decreases. The system then becomes unbalanced, the intensity of the current in one relay coil being greater than that in the other coil to cause one side or the other of the polarized relay to attract the armature **44** and complete a circuit to the reversible motor in one direction or the other. With the motor **70–4** connected to the steering mechanism as disclosed in FIG. 4, the rudder of the vessel will be appropriately actuated through the motor to execute a course correcting maneuver and to right the vessel on its previous course.

In order to prevent overcorrection of the steering response and consequent hunting effects, FIG. 4 also illustrates a form of linear feedback controller related to that shown in my copending application and operated from the rudder mechanism through a control cable **94**. The cable is shown entrained through pulleys as **96**, **98** and is connected to the adjustable arm **64***a* of potentiometer **62***a* in channel A, for example, against the bias of spring **108** also connected to the arm. The arrangement is such as to sense the displacement or amount of movement of the rudder and to introduce a correction in amplifier A that changes the current therein to bring the polarized relay back into balance and discontinue operation of the motor prior to restoration of the rudder to its original angular position, thereby to avoid continual hunting of the system. It will be appreciated that the angular position of the rudder is related to the current flowing through the meter **32** or **58**, which can be calibrated in terms thereof to provide a rudder angle indicator, if desired.

In lieu of connecting the feedback connection to control the potentiometer **62***a* in the output of amplifier A, the connection could be made to the adjustable arm of the input potentiometer R3 in the input of the amplifier. Other ways of sensing the displacement or movement of

the rudder and/or the velocity or acceleration of the movement thereof and of applying a linear proportional or anticipatory feedback connection in or correction to the control system could be employed, as will be apparent to those skilled in the art.

FIG. 5 illustrates the application of the radio directional control system of FIG. 1 with the manifold attendant advantages thereof to an automatic radio direction finder application in which the motor **70–5** is coupled through suitable reduction gearing **170** directly to the mast **18** of the antenna. With the switch **92** open, the amplifiers **24** and **25** are adjusted, as stated above, to equal conductivity or quiescent levels of current, as noted by the indications on meters **32** and **58**. With the receiver turned on and the amplifiers adjusted to equal amplification levels to produce equal output voltage swings therefrom, switch **92** is closed. Depending upon the initial attitude of the antenna, the outputs of the amplifiers **24** and **25** will be unbalanced and unequal, resulting in actuation of the polarized relay **26** to cause the closing of contacts **36, 38** or **46, 48** depending upon whether the intensity of the current in coil **34** is greater or less than that of the current in coil **50**. This results in energization and rotation of the motor **70–5** in one direction or the other to *automatically* position the antenna at an angle at which the outputs from the amplifiers **24, 25** will be equal, causing the relay to open its contacts and stop the motor.

It will be appreciated that the radio direction finder maintains the antenna in a fixed attitude relative to the transmitter and that this information may be used to advantage to steer the craft on a homing course toward the transmitter. When the course of the craft is at an angle to a line drawn between the transmitter and the craft, the orientation of the RDF controlled antenna relative to a fixed point on the craft or the direction of the course of the craft, continuously changes as the craft proceeds along its course. Such information is also used to advantage in navigating the craft.

For this purpose, there is fastened to the mast **18** of the antenna, a fixed indicating pointer element **177**, which cooperates with a stationary scale **178**, such as a compass card or rose, having a plurality of angularly spaced apart graduations thereon to provide a visible indicating instrument of the direction of the transmitting antenna relative to the position or course of the craft. As the antenna is maintained continuously oriented towards the transmitting station, the change in position or the rotation of the pointer **177** relative to the fixed reference scale **178** will indicate the angular deviation of the course of the craft from a homing course toward the transmitter. The resulting information is employed to plot or calculate the position of the craft and/or distances along the course or to the transmitter by trigonometric navigational computations.

What is claimed is:

1. A radio directional control system for automatically positioning a mechanism used in navigating a craft and comprising, in combination,

a directional antenna,

a radio receiver connected to the antenna and having an output circuit whose output characteristic rises and falls in accordance with the angular position of the antenna relative to a distant transmitter to which the receiver is tuned,

signal translating means coupled to the otuput circuit of the receiver and providing a pair of output signals therefrom one of which signals varies in intensity directly with the rise and fall of the receiver output characteristic with antenna position and the other varies in intensity inversely thereto,

means for comparing the relative intensities of said signals,

and reversible motor means for positioning said craft navigating mechanism and coupled to the comparing means to respond thereto and operate in one direction or the other in accordance wtih the relative intensities of said pair of output signals.

2. The invention in accordance with claim **1** above including means for adjusting said signals to equality at a point intermediate the maximum and minimum intensities thereof.

3. The invention in accordance with claim **1** above wherein said signal translating means comprises a pair of inversely operating signal amplifiers.

4. The invention in accordance with claim **3** above wherein said amplifiers are connected to the receiver output circuit in opposite manner and wherein each amplifier includes means for adjusting the conductivity thereof and means for adjusting the output signal therefrom.

5. The invention in accordance with claim **1** above, wherein said comparing means comprises a bipolar device operable to conduct a current in one direction to said motor when one of said pair of output signals exceeds the other and to conduct a current in the opposite direction to the motor when the latter signal exceeds the former one.

6. The invention in accordance with claim **3** above, wherein said comparing means is a polarized relay having a pair of relay operating coils each connected to the output of a different one of said amplifiers.

7. The invention in accordance with claim **3** above, wherein said amplifiers are adjusted to produce the same conductivity and wherein the output signals therefrom are adjusted to equality with the antenna oriented at substantially 45° to the distant transmitter.

8. The invention in accordance with claim **7** above, wherein said craft navigating mechanism is the mechanism for steering a vessel through the rudder thereof connected to said motor means.

9. The invention in accordance wtih claim **4** above, wherein said control system further includes a feedback controller responsive to movement of the craft navigating mechanism effected from said motor and introduces a feedback correction in the control system through one of said adjusting means of one of said amplifiers.

10. A radio directional control system for automatically positioning a mechanism used in navigating a craft having a radio receiver thereon and comprising in combination,

a directional antenna connected to the receiver whose output characteristic rises and falls in accordance with the angular position of the antenna relative to a distant transmitter to which the receiver is tuned,

signal translating means coupled to the output circuit of the receiver and providing a pair of output signals therefrom one of which signals varies in intensity directly with the rise and fall of the receiver output characteristic with antenna position and the other varies in intensity inversely thereto,

means for adjusting said signals to equality at a point intermediate the maximum and minimum intensities thereof,

means for comparing the relative intensities of said signals,

and reversible motor means for positioning said craft navigating mechanism and connected to the comparing means to respond thereto and operate in one direction or the other in accordance with the relative intensities of said pair of output signals.

11. The invention in accordance with claim **1** above, wherein said craft navigating mechanism is an automatic radio direction finder in which the motor of the control system is coupled to drive the antenna and maintain it in a predetermined attitude relative to the transmitter.

12. The invention in accordance with claim **11** above, wherein the control system controls the motor to maintain the antenna at an angle of approximately 45° to the transmitter.

13. A radio directional control system for automatically positioning a mechanism used in navigating a craft and

comprising, in combination: a directional antenna, a radio receiver connected ot the antenna and having an output circuit whose output characteristic rises and falls in accordance with the angular position of the antenna relative to a distant transmitter to which the receiver is tuned, signal translating means coupled to the output circuit of the receiver and providing a pair of dissimilar output signals which vary with the rise and fall of the receiver output characteristic in accordance with the antenna position, means for comparing said signals, and reversible motor means for positioning said craft navigating mechanism and coupled to the comparing means to respond thereto and operate in one direction or the other in accordance with the comparison of said pair of outputs signals.

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