

March 28, 1961

H. J. LETTINE ET AL

2,977,463

CONTROL SYSTEM

Filed March 21, 1957

2 Sheets-Sheet 1

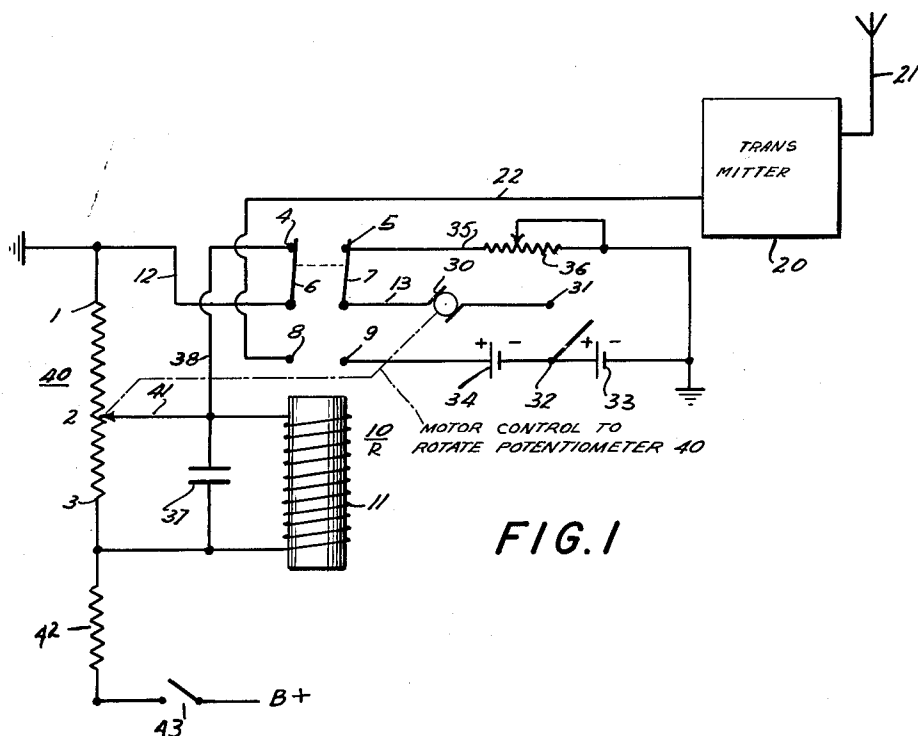


FIG. 1

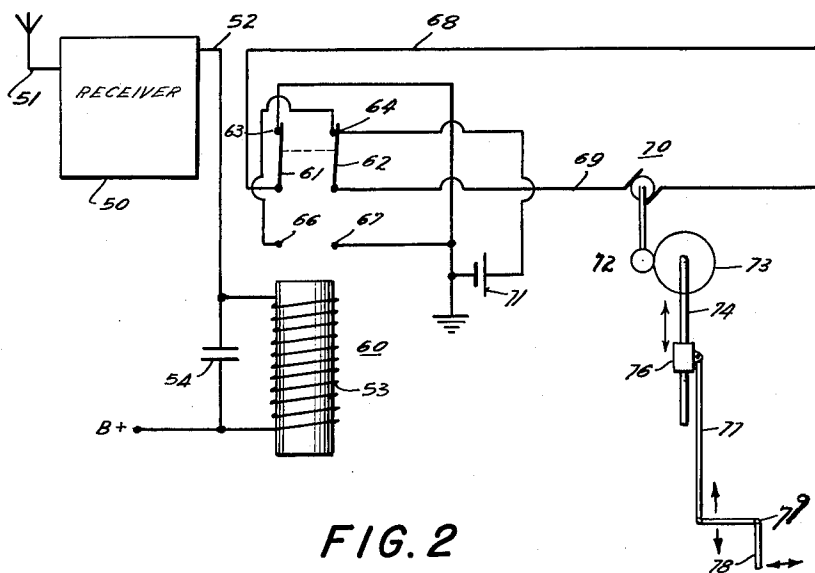


FIG. 2

INVENTORS.
ANTHONY LETTINE
HOWARD J. LETTINE

2,977,463

2 Sheets-Sheet 2

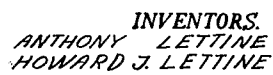


FIG. 4

1

2,977,463

CONTROL SYSTEM

Howard J. Lettine and Anthony Lettine, both of
62 Berkley St., Valley Stream, N.Y.

Filed Mar. 21, 1957, Ser. No. 647,625

5 Claims. (Cl. 250—2)

The present invention relates to a control system. More particularly, the present invention relates to a control system for remotely controlling an air-borne missile.

It is an object of the present invention to provide a new and improved control system.

A second object of the present invention is to provide a new and improved control system for remotely controlling an air-borne missile.

Another object of the present invention is to provide a new and improved control system having at least one transmitting station and at least one receiving station.

With the above objects in view, the present invention mainly consists of a control system including at least one transmitting station having means for generating and transmitting a carrier frequency, means for modulating the carrier frequency at a predetermined modulation frequency, the transmitting station also including means for varying the predetermined modulation frequency in a desired manner, and at least one receiving station remotely located from the transmitting station and having receiving and demodulating means for receiving and demodulating the transmitting modulated carrier frequency wave to obtain a wave at the modulated frequency, the receiving station including control actuating means responsive to the modulation frequency wave for actuating controls at the receiving station in accordance with the demodulated frequency wave.

In a preferred embodiment of the present invention, the receiving station is located on an air-borne missile and the controls, actuated by the control actuating means, are the elevator and the rudder of the missile to control the flight of the air-borne missile.

In the present invention the means for varying the modulation frequency are preferably constructed in the form of a "joystick," simulating an actual joystick used in an airplane.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which—

Fig. 1 is an electrical schematic diagram of the modulation frequency determining apparatus at the transmitting station;

Fig. 2 is an electrical schematic diagram showing the control actuating means at the receiving station responsive to the modulation frequency wave;

Fig. 3 is an elevational view of the manually operated control means at the receiving station;

Fig. 4 is a front elevational view of the apparatus shown in Fig. 3,

Fig. 5 is a front elevational view of a roll control arrangement for the receiving station; and

Fig. 6 is a side elevational view of the apparatus illustrated in Fig. 5.

2

Referring to the drawings and more particularly to Fig. 1, it can be seen that the transmitting station includes a transmitter 20 having an output terminal connected to an antenna 21 for transmitting a carrier frequency wave. The transmitter 20, shown only in block form, can be a conventional transmitter, the carrier frequency output of which is adapted to be keyed by modulating means.

Connected to the input of the transmitter 20 is a conductor 22, the other end of which is connected to a fixed contact 8 of a relay 10 having a relay winding 11 and three other fixed contacts 4, 5 and 9 respectively.

The relay 10 also includes two movable armatures 6 and 7 which are shown respectively connected to the fixed contacts 4 and 5. In Fig. 1, the unenergized condition of the relay 10 is illustrated. In the energized condition, the movable armatures 6 and 7 are respectively moved into engagement with the fixed contacts 8 and 9 instead of 4 and 5.

The armature 6 is connected by a conductor 12 to the electrical ground and the armature 7 is connected by a conductor 13 to one side of a motor 30, the other side of which is connected to the fixed contact of a switch 31. The movable contact of the switch 31 is connected to a junction point 32 which is respectively connected to the positive terminal of a direct current source 33 and to the negative terminal of a direct current source 34.

The positive terminal of the source 34 is connected to the fixed contact 9 of the relay 10 while the negative terminal of the source 33 is connected to the electrical ground.

The fixed contact 5 is connected by a conductor 35 to one end of a variable resistor 36, the other end of which is connected to the electrical ground.

Connected across the winding 11 of the relay 10 is a capacitor 37 having one plate thereof connected by a conductor 38 to the fixed contact 4 and by a conductor 39 to the movable arm 41 of a potentiometer 40.

The potentiometer 40 has an upper end point 1 connected to the electrical ground and a lower end point 3 connected to the other plate of the capacitor 37 and also connected to one end of a resistor 42. The other end of resistor 42 is connected to the fixed contact of a switch 43, the movable contact of which is connected to a source B+ of operating potential.

The purpose of the apparatus shown in Fig. 1 is to generate desired modulating frequencies for keying the transmitter 20 so as to modulate the carrier frequency wave output of this transmitter in a desired manner to control the control actuating means in the remote receiver station.

In operation, when the switch 43 and is closed and the switch 31, 32 is open, the relay winding 11 of relay 10 has a potential applied thereto depending on the voltage divider arrangement made up of the resistors 42 and the potentiometer 40 and the position of the movable arm 41 of the potentiometer 40. If the potential applied across the relay winding 11 is sufficient to energize the same, the armatures 6 and 7 will be moved out of contact with the fixed contacts 4 and 5 and respectively into contact with the fixed contacts 8 and 9.

When the armature 6 is attracted to the fixed contact 8, ground potential is applied to the conductor 22 to make it possible to key the transmitter and modulate the carrier frequency output thereof as described below. As long as the switch 31 remains open, the electrical connection between the movable armature 7 and the fixed contact 9 will have no effect.

However, when the movable armature is moved out of contact with the fixed contact 4, the portion of the potentiometer 40 between the tap 41 and the end point 1 will no longer be short circuited so that the voltage applied

across the relay winding 11 due to the B+ source will be decreased. However, due to the action of the capacitor 37, this voltage will not immediately drop to zero. The relay winding 11 will accordingly remain energized for a time period depending on the time constant of the capacitor 37 and the portion of the potentiometer connected thereacross. Of course the time constant is determined by the capacitance of the capacitor 37 and the resistance of the portion of the potentiometer 40 connected thereacross.

When the potential across the relay winding 11 drops below the amount sufficient to maintain the same in an energized condition, the movable armatures 6 and 7 will be returned to their initial unenergized position by restoring means, not illustrated. It is clear that the restoring means may be springs for example.

As soon as the armature 6 again contacts the fixed contact 4, the upper portion of the potentiometer 40 between the movable arm 4 and the end point 1 will again be short circuited to increase the portion of the potential applied across the relay winding 11. This again energizes the relay winding 11 and the movable armatures 6 and 7 return into contact with the fixed contacts 8 and 9.

The above described cycle is repeated at a repetition rate depending upon the position of the movable tap 41 of the potentiometer 40. The modulation frequency can be varied between two extreme positions 1 and 3 of the potentiometer 40 by means of the tap 41 thereof. That is, if the potentiometer tap 41 is moved to the point 1 so that the tap is substantially connected to the electrical ground, the relay winding 11 will become energized as soon as the switch 43 is closed and will remain in energized condition. Therefore, the electrical ground potential will be continuously applied to the conductor 22 to provide a constant voltage superimposition for the carrier frequency wave output of the transmitter 20.

Conversely, if the potentiometer tap 41 is moved towards the end point 3 of the potentiometer 40, the relay winding 11 and the capacitor 37 will be substantially short circuited so that the relay winding 11 will not be energized regardless of the position of the switch 43 and accordingly no modulation will be applied to the carrier frequency output of the transmitter 20.

It is therefore seen that by manually controlling the position of the tap 41 of the potentiometer 40, it is possible to vary the modulation frequency for the transmitted carrier frequency wave.

Automatic control means are also provided in the embodiment illustrated in Fig. 1. These control means include the motor 30, the shaft of which is connected to the winding of the potentiometer 40 so as to rotate the entire potentiometer winding with respect to the movable tap 41 thereof, regardless of any set position of the tap 41, in a direction determined by the direction of rotation of the shaft of the motor 30. It can be seen that when the switch 31 is closed, and the relay 10 is energized by the direct current source B+, the movable armature 7 moves back and forth in synchronism with the movable armature 6 as described above.

When the armature 7 is in contact with the fixed contact 9, the motor 30 is energized by the direct current source 34 and the shaft thereof is rotated in a direction determined by the polarity of the source 34. When the armature 7 is in contact with the fixed contact 5, the motor 30 is energized by the direct current source 33 and is rotated in the opposite direction since the polarity of the direct current source 33 is opposite to the polarity of the direct current source 34. In the unenergized condition of the relay winding 11, the motor 30 is connected in series with the variable resistor 36 for reasons which will be explained hereinafter.

When the relay winding is in energized condition and the armature 7 is connected to the fixed contact 9, the motor 30 is rotated by the source 34 in a direction so that the end point 3 of the potentiometer 40 is brought

closer to the tap 41 thereof. This tends to de-energize the relay winding 11 more quickly. On the other hand when the relay winding is in unenergized condition, the armature 7 making contact with the fixed contact 5 causes the source 33 to rotate the motor 30 in the reverse direction so that the end point 1 of the potentiometer 40 is driven toward the tap 41. This serves to end the de-energized period of the relay winding 11 more quickly.

Accordingly, the action of the motor 30 serves to oscillate the winding of the potentiometer 40 back and forth quickly so that the tap 41 is effectively maintained at the central position 2 of the potentiometer 40, if so set manually before, and the energization and de-energization periods for the relay winding 11 are substantially equal. With this condition, the carrier frequency wave is in modulated and in unmodulated condition for approximately equal time periods. The purpose of this arrangement will be described hereinbelow with respect to the receiver controls.

Referring now to Fig. 2, the receiving station includes receiving and demodulating means 50 which is connected to an antenna 51 for receiving and demodulating the carrier frequency waves received by the antenna 51 and transmitted from the antenna 21. Due to the action of the receiver and demodulator, there appears on the output conductor 52 of the demodulating means 50, a wave which corresponds to the modulation frequency wave used to modulate the carrier frequency wave at the transmitter station.

This modulation frequency wave is applied to the relay winding 53 of a relay 60 which has connected thereacross a capacitor 54. The opposite end of the relay winding 53 is connected to a source of operating potential B+. The relay winding 53 is accordingly energized and de-energized in synchronism with the modulation frequency appearing on the conductor 52.

The relay 60 has two movable armatures 61 and 62 which in the de-energized condition of the relay can make contact with the fixed contacts 63 and 64 respectively. In the energized condition of the relay 60, the armatures 61 and 62 make respective contact with the fixed contacts 66 and 67.

The armature 61 is connected on a conductor 68 to one side of a motor 70, the other side of which is connected by a conductor 69 to the armature 62. It can be seen that when the armatures 61 and 62 are in the illustrated position, the motor 70 is energized by the direct current source 71 and is rotated in a direction determined by the polarity of this source 71.

When the relay 60 is energized, the armatures 61 and 62 are respectively connected to the contacts 66 and 67 to connect the source 71 to the motor with reversed polarity so that the motor 70 is rotated in the opposite direction. That is, it can be seen that the fixed contacts of the relay 60 are connected in the manner of the reversing switch.

The motor 70 is connected to a worm 72 which in turn is meshed with the worm gear 73 having fixedly connected thereto a threaded rod 74. Threaded on the rod 74 is an internally threaded bushing 76 which is adapted to move along the rod 74 in a direction determined by the direction of rotation of the rod 74.

When the receiving station is connected for the purpose of controlling an air-borne missile, the arrangement shown in Fig. 2 is mounted on the air-borne missile and the bushing 76 is connected by a lever 77 to the control surface 78 at the pivot point 79. The control surface can be the rudder or the elevator of the missile, for example.

Accordingly, in operation, the relay 60 will be energized and de-energized for respective time periods depending upon the modulation frequency determined at the transmitter. If the energization and de-energization time periods for the relay 60 are equal, it can be seen that the control surface 78 will be moved back and

forth precisely the same amount so that the missile being guided by the control surface will continue in its fixed direction. Actually, it is to be appreciated that the energization and the de-energization of the motor 70 is for such short time periods that for all practical purposes, the control surface 78 is held in a fixed position.

However, if it is desired to move the control surface in such a manner so as to change the direction of the missile, the tap 41, of Fig. 1 of the potentiometer 40 is moved in a direction to increase either the energization or the de-energization time period. That is, if the modulation frequency as received in the receiver of Fig. 2 is such that the relay 60 is energized for time periods longer than the de-energization periods thereof, it is clear that the motor 70 will move the control surface 78 a greater amount in one direction, during the energization of the relay 60, than in the other direction, during the de-energization thereof. Accordingly, the resultant direction of the control surface 78 will be changed in a predetermined manner depending on the direction of the change and the amount thereof.

If, in the transmitter of Fig. 1, the switch 31 is open so that the automatic servo feedback mechanism provided by the motor 30 is not used, the change in direction is provided by moving the tap 41 manually toward the end point 1 or the end point 3 depending on which change of direction is desired for the air-borne missile. When the missile has changed its direction the proper amount and it is desired to maintain this missile in the new fixed direction, the manually operated tap 41 is merely moved back to the central position 2 so that the energization and de-energization time periods are again substantially equal.

If the automatic follow mechanism provided by the motor 30 is to be used, the tap 41 is merely moved to either end position depending on the desired direction of change and the motor 30, upon closure of the switch 31 will move the entire winding of the potentiometer with respect to the set position of the tap 41 so that the tap 41 will again be positioned back opposite the central point 2 of the winding.

It should be appreciated that in the transmitting station, two separate modulating frequency controls can be provided if two different control surfaces on the air-borne missile have to be controlled. That is, one modulation frequency arrangement would be used for the rudder of the air-borne missile, for example and the other for the elevator thereof. In the receiving station, tuned circuits may be provided, the output of one of the tuned circuits being connected to the control circuit for the rudder and the other to the control circuit for the elevator. The modulation frequency for the rudder will therefore only control the rudder and the modulation frequency for the elevator will therefore be used only for the control of the elevator.

Referring now to Figs. 3 and 4, an arrangement will be described wherein a single manual element can be used for simultaneously controlling the rudder and elevator control signals at the transmitter station by using two separate modulation devices. In Figs. 3 and 4, a support member 81 can be seen on which is rotatably mounted, at the upper portion thereof, a shaft 82. Fixedly connected to the shaft 82 is a spur gear 83 which is meshed with a second gear 84. The gear 84 is fixedly connected to the rotatable shaft of a potentiometer 86 which is equivalent to the type of potentiometer shown in Fig. 1, namely the potentiometer 40.

The housing of the potentiometer 86 is fixedly connected to a gear 87 which is meshed with a worm gear 88 fixedly connected to the shaft of a motor 89.

It can be seen that the movable shaft of the potentiometer 86 can be adjusted by rotation of the shaft 82, thereby rotating the gear 83 and the gear 84 while the housing of the potentiometer 86 is maintained in fixed position by the gear 87 being at standstill.

When the motor 89 is energized, the worm 88 connected thereto rotates the gear 87 to thereby rotate the housing of the potentiometer 86 while the tap or shaft of the potentiometer 86 is held in fixed position by the gear 84 being at standstill.

As can best be seen in Fig. 4, a pin 91 is connected to the shaft 82 at one of its ends and at the other of its ends is connected to a gear 92. The gear 92 has a manually operable handle 93 for varying the position thereof about the pin 91. The gear 92 meshed with a gear 94 which is connected to the shaft 41' of the potentiometer 40. The housing of potentiometer 40 is fixedly connected to a gear 95 which is meshed with a worm 96 fixedly connected to the shaft of the motor 30 so as to rotate therewith.

It can be seen that in operation, the handle 93 can be used to rotate the shaft 82 in direction of arrows A to control the movable tap on the potentiometer 86 and also in direction of arrows C to rotate the shaft 41' to control the position of the tap 41 on the potentiometer 40.

As is shown, the shaft 82 carries a bracket 82' in which the pin 91 is mounted, similarly a second pin 41' as mentioned above. In addition, a gear 83 is attached to the shaft 82 in transverse direction so as to mesh with a smaller gear 84 rotatably supported in a portion 81' of the frame or housing 81. The shaft of the gear 84 is at the same time the tap carrying shaft of the potentiometer 86. The winding and housing of this potentiometer 86 is attached to a worm gear 87 which meshes with a worm 88 driven by a motor 89. Thus, when the handle 93 is swung in direction of arrows A the movable tap of the potentiometer 86 is moved along its winding, while independently the potentiometer winding may be rotated by the action of motor 89.

It will be understood that the potentiometer 86 and its movable tap function exactly like the potentiometer 40 and its movable tap 41 and constitute the control elements of a circuit arrangement analogous to that of Fig. 1.

It is clear that the arrangement shown in Figs. 3 and 4 is similar to a "joystick" which is used for controlling the rudder and elevator controls of an airplane. Therefore, an operator can move the handle 93 from side to side in one plane to control one of the control surfaces and move the handle 93 back and forth in a plane transverse thereto to control the other of the control surfaces. It is clear that the handle 93 can be moved to any of the intermediate positions to provide simultaneous control for both the rudder and control of the remote air-borne missile.

Therefore, with the present invention, it can be seen that an operator can manually position the movable taps of the potentiometers 40 and 86 in the transmitter circuit for supplying the proper modulation frequencies for the carrier frequency waves transmitted by the transmitter antenna 21. In the receiver, the control surfaces are properly positioned by control surface actuating members which are moved in accordance with the received modulation frequency waves.

The potentiometer 36, Fig. 1, is used to compensate for creeping of the rudder or elevator of the missile being guided. This compensates for any time delay introduced by the relay operation in the receiver when the same is energized less than it is de-energized so that the movement of the motor 30 in the missile will be longer in one direction of rotation than in the other. Since the potentiometer 36 is in series with the motor 30 it is clear that the motor 30 will turn the potentiometer 40 at a slow rate depending upon setting of 36 when the relay 10 is in the de-energized position. This will keep the particular control surface in the remote missile at a fixed position to eliminate the possible creeping thereof.

Referring now to Fig. 5, a pendulum 111 is shown connected to the shaft 112 of a potentiometer 114. The case 113 which is rigidly attached to the missile itself

thereby providing proper stabilizing control for the missile.

A motor connected in circuit with the potentiometer 114 is connected to a pair of control surfaces through a worm gear and differential gear arrangement. When the missile is level, the tap connected to the potentiometer arm 112 is in the center position, sending equal positive and negative pulses to the motor, causing the control surfaces to stand still. When the missile rolls, the pendulum or gyroscope moves the potentiometer arm 112, making one pulse longer than the other (depending on the direction of the roll) causing the motor to rotate, moving the control surfaces in opposite directions to correct the roll.

If a closed servo loop system is desired, another small motor is connected in parallel to the control surface motor and attached to the potentiometer case 113, the same as the follower motors in the transmitter control box.

Another method of obtaining a closed servo loop would be to mount the potentiometer case on the differential gear arrangement.

The advantage of this system is that it eliminates dead space, because it corrects instantly.

This system can also be used as an automatic pilot, when the potentiometer is attached to a gyroscope indicating direction.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of control systems differing from the types described above.

While the invention has been illustrated and described as embodied in apparatus for remotely controlling airborne missiles, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can, by applying current knowledge, readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. In a transmitter having modulating means, in combination, energizing means for energizing the transmitter modulating means, switch means connected in circuit between said energizing means and the modulating means and movable between a circuit closing position wherein the modulating means is energized and a circuit opening position wherein the modulating means is de-energized, electromagnetic means for moving said switch means between its circuit opening and closing positions, and frequency determining means connected to said electromagnetic means for controlling the frequency at which said electromagnetic means moves said switch means be-

tween its circuit opening and circuit closing positions, said frequency determining means including a capacitor connected in parallel with said electromagnetic means, and a potentiometer connected in circuit with said capacitor, said potentiometer having a variable resistance which in combination with the capacitance of said capacitor determines the frequency of operation of said electromagnetic means.

2. Apparatus claimed in claim 1 wherein said frequency determining means includes a capacitor connected in parallel with said electromagnetic means, and a potentiometer connected in circuit with said capacitor, said potentiometer having a variable resistance which in combination with the capacitance of said capacitor determines the frequency of operation of said electromagnetic means.

3. Apparatus as claimed in claim 1 wherein moving means are connected to said potentiometer for varying the resistance thereof in opposite directions respectively, in each of said switch positions.

4. Apparatus as claimed in claim 3 wherein said moving means includes a motor having a rotatable shaft connected to the housing of said potentiometer, a second energizing means connected in circuit with said motor in one of said switch positions for rotating said motor in a first direction and a third energizing means connected in circuit with said motor in the other of said positions for rotating said motor in the direction opposite to said first direction.

5. Apparatus as claimed in claim 3 wherein said moving means includes a support member and an elongated member rotatably mounted on said support member, a shaft mounted on said elongated member, substantially transverse thereto and rotatable with respect to said elongated member, at least one motor mounted on said support means and having a rotatable shaft, first coupling means for coupling said rotatable shaft to said potentiometer for rotating the same in a direction depending upon the direction of rotation of said rotatable shaft of said motor, and second coupling means connecting the movable tap of said potentiometer to said elongated member, whereby when said elongated member is rotated, the shaft of said potentiometer is rotated by said second coupling means while said potentiometer is prevented from rotating, and when said motor is energized, the rotatable shaft thereof rotates said potentiometer while the potentiometer shaft is prevented from rotating.

References Cited in the file of this patent

UNITED STATES PATENTS

1,884,655	Gebhard	Oct. 25, 1932
1,894,952	Gebhard	Jan. 24, 1933

OTHER REFERENCES

Publication (1), QST, February 1952, "A Radio Control System for Models," pages 17-19.

Publication (2), Radio and Television News, August 1950, "Radio Control of Model Boat," pages 29-33.