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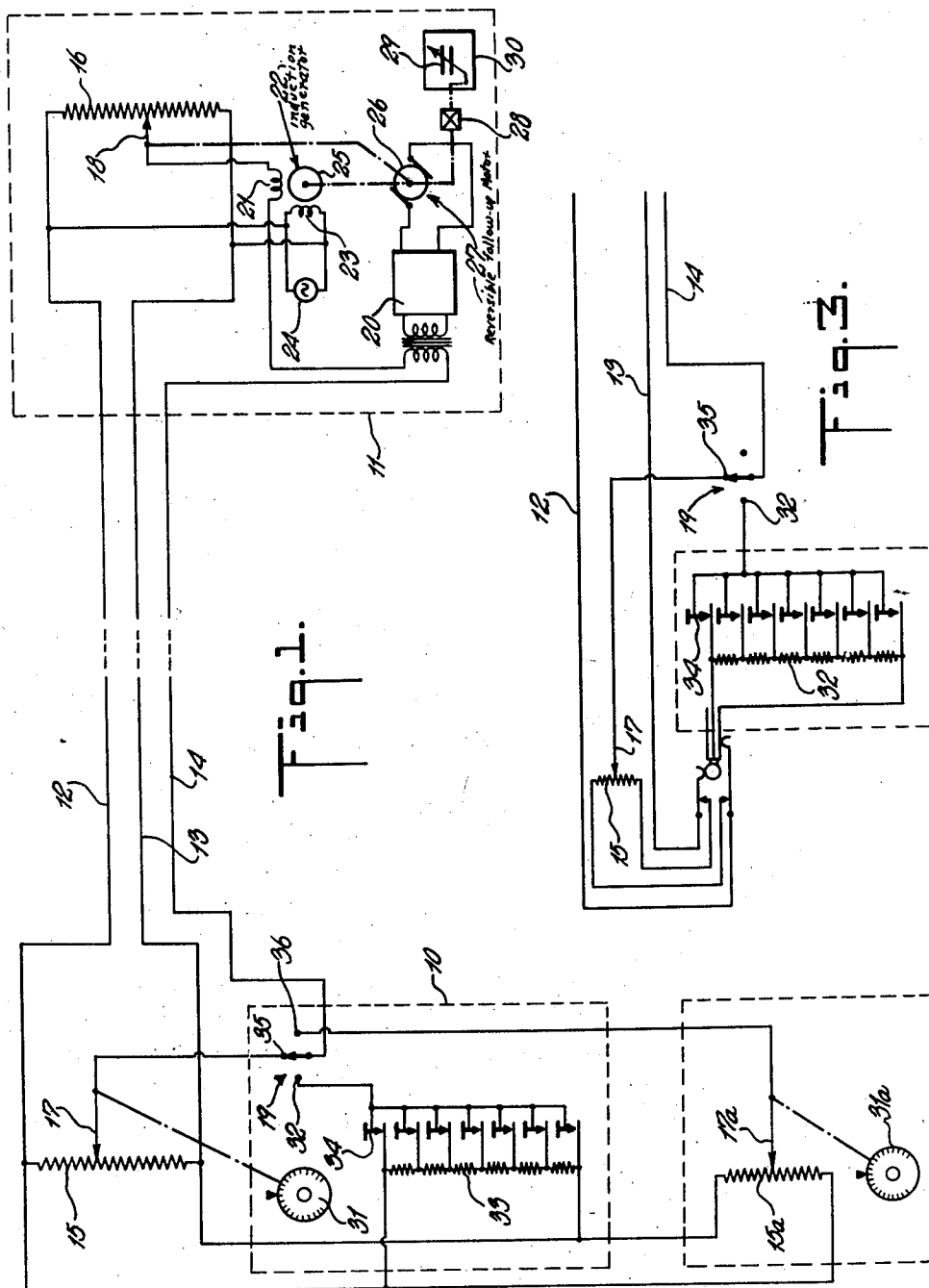
F. L. MOSELEY

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REMOTELY TUNED RADIO APPARATUS AND THE LIKE

Filed May 21, 1947

2 Sheets-Sheet 1



INVENTOR
FRANCIS L. MOSELEY

BY *John J. Logan*
ATTORNEY

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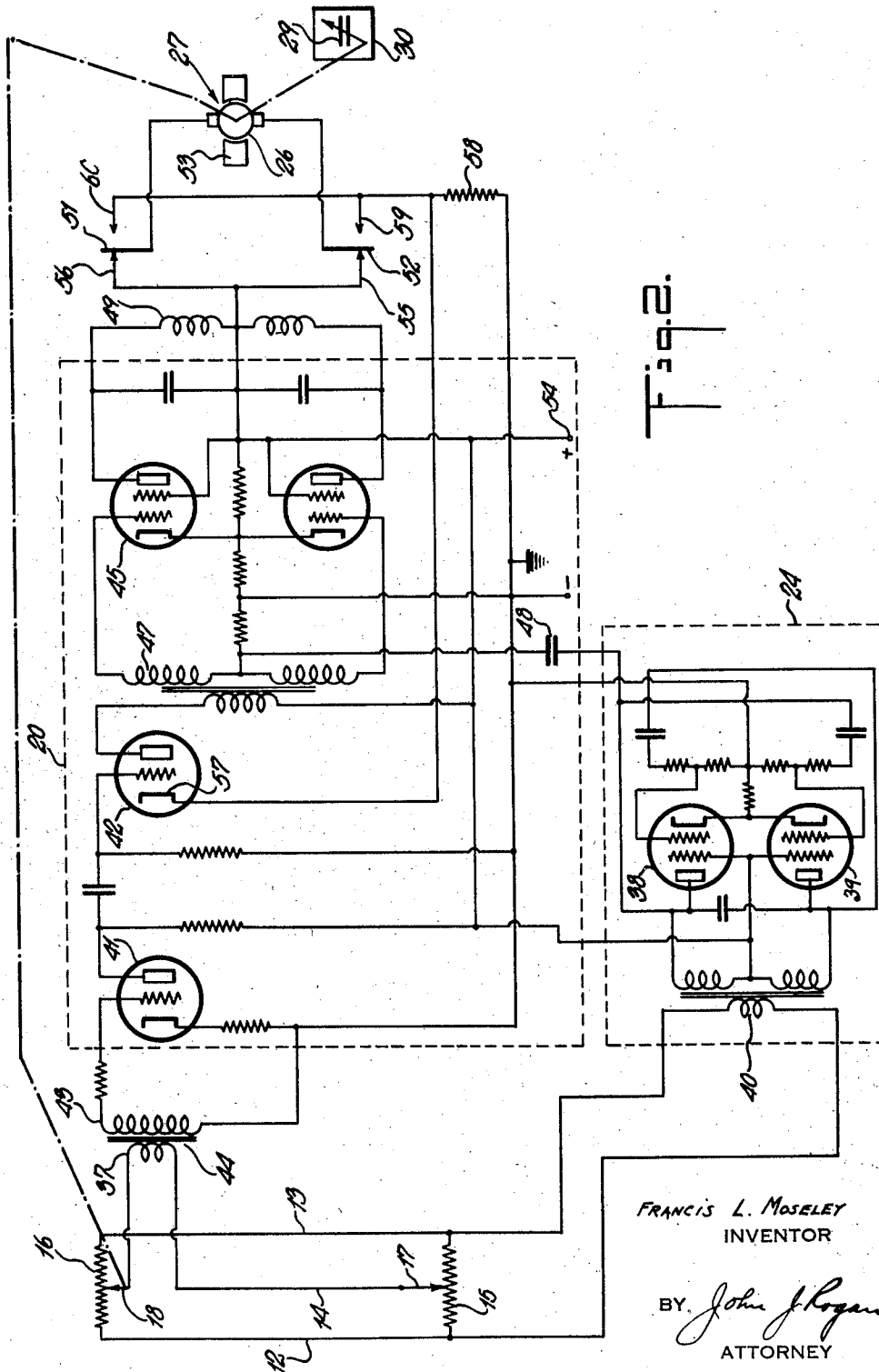
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2 Sheets-Sheet 2



UNITED STATES PATENT OFFICE

2,492,392

REMOTELY TUNED RADIO APPARATUS
AND THE LIKEFrancis L. Moseley, Cedar Rapids, Iowa, assignor
to Collins Radio Company, Cedar Rapids, Iowa,
a corporation of Iowa

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This invention relates to the tuning of radio devices and more particularly to remote controls for radio apparatus and the like.

A principal object of the invention relates to an improved remote tuning control for radio apparatus whereby accuracy and speed of remote tuning are enhanced.

Another principal object is to provide an automatic tuning control arrangement for radio apparatus and the like, and incorporating novel circuit arrangements for reducing hunting or over-running of the motor which is used to operate the tuning controls.

A feature of the invention relates to an improved automatic tuning control arrangement for radio apparatus and the like, employing a control circuit of the balanced bridge type, in conjunction with a special anti-hunting control employing a motor of the induction type.

Another feature of the invention relates to an improved automatic tuning control arrangement for radio sets and the like employing a power motor for operating the tuning controls of the set, the motor in turn being controlled by a balanced bridge, in conjunction with a special relay circuit for operating the tuning control in discrete increments in proportion to the extent to which they must be eventually moved to the desired tuning position.

A further feature relates to a novel form of anti-hunting circuit for servo-mechanisms generally.

A still further feature relates to the novel organization, arrangement and relative interconnection of parts which cooperate to provide an improved automatic tuning control arrangement for radio apparatus and the like.

In the drawing which shows certain preferred embodiments,

Fig. 1 is a composite schematic wiring diagram of a system embodying the invention.

Fig. 2 is a modification of the system of Fig. 1.

Fig. 3 is a modification of a portion of the system of Fig. 1.

While the invention is applicable to the tuning of radio apparatus generally, it finds immediate utility in connection with radio equipment used on military and transport aeroplanes where the radio apparatus is usually mounted at some convenient centralized location and arranged for full control by the pilot in the cockpit. For this purpose, it has been customary to operate the tuning controls of the radio apparatus through flexible shafting, which has been found satisfactory where the length of shafting is not too great. On the other hand, when the length of shafting is greater than 15 feet, the remote control becomes very troublesome. The present invention obviates the use of such flexible shafting and permits the radio apparatus to be controlled from more than one point.

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Referring to Fig. 1, the block 10 represents in schematic form a control panel located for example in the cockpit of an aeroplane, while the rectangle 11 represents the location of the radio apparatus and its motor mechanism at some point remote from the cockpit. As shown, the control panel is connected to the radio apparatus by three wires 12, 13, 14. These wires terminate at the panel in a potentiometer resistance 15, and at the remote point in a similar potentiometer resistance 16. Each of the resistances is provided with an adjustable slider arm contact 17, 18, which are interconnected by the wire 14, through the intermediary of the three-point manual switch 19, the input coupling circuit of amplifier 20, and one winding 21 of any well-known form of induction generator 22. The other winding 23 of this generator is fed with an alternating current of uniform amplitude from an oscillator 24 which is bridged across the conductors 12, 13.

The rotor 25 of the induction generator is mechanically connected to the armature 26 of the reversible follow-up motor 27. The winding 21 is connected into the balancing bridge circuit in such a direction to supply a signal which tends to oppose rotation of motor 27. The number of revolutions per minute of armature 26 is therefore a direct function of the amount of current flowing through the winding 21 of the induction generator 22. As this current decreases, the rotor 25 becomes less and less effective in assisting the rotation of armature 26. In other words, as the current through winding 21 decreases, there is a corresponding increase of the slowing down of the armature 26. Eventually, when the current through winding 21 becomes zero, the armature 26 is stopped thus providing a smooth dead beat control action on the rotation of armature 26.

The resistances 15 and 16 are interconnected with the oscillator 24 to form a Wheatstone bridge, consequently the magnitude of the current flowing through winding 21 of the induction generator, will be dependent upon the extent of unbalance of the bridge. When the bridge is completely balanced, no current flows through winding 21, the gain of amplifier 20 is reduced to a minimum, and no current flows through the armature 26 which therefore comes to rest. The armature 26 is connected through suitable reduction gearing 28, to the tuning control or controls 29 of the radio apparatus 30. The armature 26 is likewise connected through suitable reduction gearing (not shown) to the slider arm 18. Likewise, slider arm 17 is geared through suitable reduction gearing (not shown) to the calibrated control knob 31. Consequently, when the pilot turns knob 31 to a new setting, the bridge is unbalanced causing follow-up motor 26 to operate in the desired direction depending upon the

direction of the current flowing through the conductor 14 to the amplifier 20. Preferably, although not necessarily, all the electric power is derived from a low voltage D. C. source, such as a 28 volt storage battery. This low voltage can be converted into suitable higher voltages in the well-known manner, to supply the necessary operating potentials for the electron tubes in amplifier 20 and for the oscillator 24, which may be designed to generate for example at a medium low frequency of 300 C. P. S.

Preferably, the unbalanced bridge current is applied to the input of amplifier 20 so as to control the gain thereof in the manner to be described in connection with the embodiment of Fig. 2. With the combination of controls illustrated in Fig. 1, the follow-up motor 27 continuously decreases its speed as the bridge approaches its balance point and the rate of decrease is proportional to the rate of decrease in the unbalance bridge current, thus providing a smooth dead beat control action on the movement of the tuning control 29.

In certain cases, it is desirable, instead of requiring the pilot manually to rotate knob 31 to a precise setting, to allow him merely to operate a button for such setting. For this purpose, the switch 19 is turned to close a circuit through contact 32 which renders effective a series of tapped resistors 33 bridged across the conductors 12, 13. Each tap of the resistor 33 is connectable to a corresponding push button 34, to contact 32, and thence to conductor 14. Each of the buttons 34 can be allocated to a particular frequency channel to which the radio set 30 is to be tuned so that the operation of a button for a new setting unbalances the bridge and causes follow-up motor 27 to turn the tuning control 29 to the desired setting as described above. This arrangement is particularly convenient, for example in flying a certain airway route since the various radio range stations are represented by the buttons 34 which can be arranged in the order in which the stations are located on the route. The pilot can thus tune to the desired navigational stations in succession, by simply depressing a push button 34 each time he enters the operating zone of a new station. It will be understood of course, that the buttons 34 are of the automatic locking and unlocking type so that when one button is operated, it releases the previously operated button. It will be understood that such a push button arrangement, instead of being permanently connected in circuit as shown in Fig. 1, can be mounted in a strip and provided with a suitable plug and jack arrangement as schematically shown in Fig. 3, so that each strip of buttons previously adjusted to the selected groups of stations can be plugged in for any desired navigational course. When it is desired to revert to manual tuning by knob 31, switch 19 is turned to close on contact 35, thus connecting the desired control potentiometer 15, 17, in circuit.

If operation is desired from more than one control point, the switch 19 may be provided with one or more additional contacts 36 which can be connected to a potentiometer arm 17a cooperating with a corresponding potentiometer resistance 15a and calibrated knob 31a at the additional control point. The resistance 15a is bridged across the conductors 12, 13, and the slider arm 17a is ganged to the knob 31a in the manner above described for the corresponding elements 17 and 31.

Referring to Fig. 2, there is shown in schematic detailed form a typical amplifier 20 and oscil-

lator 24 that may be used in the system of Fig. 1. However, in Fig. 2, the manner of controlling the follow-up motor 27 is somewhat different. In Fig. 2, the pilot's control potentiometer 15, 17, and the remote-controlled potentiometer 16, 18, are the same as in Fig. 1 and together with the conductors 12, 13, 14, and oscillator 24, they constitute an automatically balanced Wheatstone bridge. However, the induction generator winding 21 of Fig. 1 is omitted. The oscillator 24 may be of any well-known type, comprising for example a pair of grid-controlled electron tubes 38, 39, which are connected in push-pull relation to the primary winding of an audio frequency coupling transformer, the secondary 40 of which is bridged across conductors 12 and 13. The oscillator tubes 38 and 39 are arranged to generate, preferably a medium frequency alternating current for example of 300 C. P. S. The amplifier 20 may consist of the two conventional amplifier stages 41, 42, the input of stage 41 being controlled from the secondary winding 43 of the transformer 44, whose primary is energized in accordance with the unbalance current of the bridge. This amplifier also preferably includes an additional push-pull relay control stage comprising the tubes 45, 46. The control grid or input circuits of the tubes 45 and 46 are connected in push-pull relation by means of transformer 47 to the output of amplifier tube 42, and these control grids of tubes 45 and 46 are also supplied through condenser 48 with a portion of the 300 C. P. S. voltage from oscillator 24. Connected in the plate circuits of tubes 45 and 46 in push-pull relation are the windings 49, 50, of respective electromagnetic relays each having an armature 51, with associated fixed contacts.

The armatures 51 and 52 together with their associated contacts act in the nature of a reversing switch for reversing the direction of current flow through armature 26 of the follow-up motor 27 which preferably has a permanent magnet D. C. field structure 53. The unbalance current from the bridge, corresponding to a new setting, after being amplified in amplifier tubes 41, 42, reaches the input circuits of control tubes 45 and 46, where it is added to or subtracted from the A. C. voltage which is supplied directly from the oscillator 24 through condenser 48. Consequently, an unbalance of the control potentiometers in one direction will increase the plate current of tube 45 and will operate relay armature 51; while an unbalance in the opposite direction will increase the plate current of tube 46 and will operate relay armature 52. It will be observed that the positive terminal 54 of the low voltage D. C. source which supplies the D. C. potential for the electrodes of the various tubes, is also connected to the relay contacts 55, 56, and thence through the corresponding relay armature 51, 52, to the motor armature 26. Thus, motor 27 can be controlled as to direction of rotation depending upon which one of the relays 49, 50, is energized and therefore of course depending upon the direction of unbalance in the potentiometer bridge circuit. When the plate current of tubes 45, 46, is below a predetermined minimum level, the relays 49, 50, are not energized sufficiently to attract their armatures 51, 52, which therefore remain in engagement with contacts 59 and 60. In order to prevent hunting of the armature 26, the electron-emitting cathode 57 of amplifier tube 42 is connected to ground through a cathode load resistor 58, so that the plate current of the amplifier tube

42 flows through this resistance. The ungrounded end of this resistance is also connected to the relay contacts 59, 60, so that the resistance 58 is effectively connected in series with the motor armature 26 when either one of the relays 49, 50, is energized. Consequently, the negative bias of the control grid 61 of tube 42 with respect to its cathode 57 is not only a function of the plate current of tube 42 but is also a function of the current flowing through the motor armature 26.

In the well-known manner, the voltage drop across resistor 58 is applied to the cathode 57, so as to decrease the gain of this amplifier stage whenever motor current flows through resistance 58. By this arrangement, the amplifier system is maintained at high sensitivity when no current is flowing through the armature 26. However, when an unbalance of the bridge occurs and current flows through the armature 26, the sensitivity of the amplifier is greatly reduced. In other words, at the beginning of the follow-up operation, as soon as the bridge is unbalanced, current begins to flow through armature 26 but immediately thereafter the gain of amplifier 42 is reduced by resistance 58 causing relays 49 and 50 to retract their armatures against contacts 59 and 60, thus disconnecting the motor armature from the D. C. terminal 54. Immediately thereafter, the bias on cathode 56 is changed since the armature current no longer flows through resistance 58 and the sensitivity of the amplifier 42 is again restored. Thus, the motor 27 operates in a rapid series of small steps controlled by the rapid opening and closing of the relays 49, 50, whenever the unbalance current of the bridge is small. However, when a large unbalance bridge current exists, the larger signal is applied to grid 60 but the plate current of tube 42 is not entirely cutoff or neutralized by the bias which is applied to cathode 57 from resistance 58. Consequently, for large values of unbalance bridge current, the relays 49 and 50 are held in their operated position to maintain a circuit through the motor armature 26 and the motor therefore operates at full speed. As the balance point is approached however, the input signal to grid 61 is reduced and the gain reduction determined by the voltage drop through resistance 58, again takes control and the above-described "nibbling" action of the relays 49 and 50, occurs, thus slowing down the motor preparatory to its stopping at the correct balance point. In other words, for large unbalanced conditions of the bridge, the motor 27 operates substantially continuously at relatively high speed because of the high level signal applied to grid 61 from the bridge. As the balance point is reached, the relays 49 and 50 take control and cause the motor to be operated in a rapid series of small steps until the balance point is reached. This arrangement has been found to be quite successful in practice and results in relatively fast and accurate positioning of the tuning control 29 of the radio apparatus 30.

While in the drawing the potentiometer arms 17, 18, are shown as traversing the respective potentiometer resistances in a single traverse, it will be understood that the arms 17, 18, may be connected to a lead screw arrangement or the like, requiring for example ten complete turns to traverse the complete length of the respective potentiometer resistances. It has been found that with such an arrangement, it is possible to set the shafts of the tuning elements 29 by remote control as above described to within

plus or minus $\frac{1}{10}$ degree of any desired position. If the devices 29 are for example tuning condensers of the 180° rotational type, this enables the tuning range to be divided into a minimum of 1800 parts. Consequently, on radio range operation where the coverage is continuously from 200 to 400 kilocycles, a reset accuracy of plus or minus .11 kilocycles is possible.

Various changes and modifications may be made in the disclosed embodiments without departing from the spirit and scope of the invention.

What is claimed is:

1. An automatic follow-up system for a device to be automatically set in different selective positions, comprising a follow-up motor for operating said device, a source of follow-up voltage whose initial amplitude corresponds to the extent to which the device must be operated from a previous setting to a new setting, an electron tube amplifier for said follow-up voltage, a separating motor supply circuit controlled by the output of said amplifier, gain control means for said amplifier and means automatically energizing said gain control means to control the sensitivity of said amplifier jointly by the plate-to-cathode current of said amplifier and by the power current flowing through the motor.

2. An automatic follow-up system according to claim 1 in which the means for controlling the gain of said amplifier comprises a bias control resistor which is connected in common in the plate-to-cathode circuit of the amplifier and in series with the power current flowing through said motor.

3. An automatic follow-up system according to claim 1 in which the means for controlling the gain of said amplifier comprises a bias resistor through which the plate-to-cathode current of said amplifier flows and through which the armature current of the motor also flows.

4. An automatic follow-up system according to claim 1 in which the means to control the gain of said amplifier comprises a grid bias resistor connected as a cathode load for said amplifier, means also connecting said resistor in series with the D. C. armature circuit of said motor, and a relay for controlling the opening and closing of said armature circuit, said relay maintaining said armature circuit open except when a predetermined minimum current flows in the output of said amplifier.

5. An automatic follow-up system according to claim 1, in which the means to control the gain of said amplifier comprises a grid bias resistor connected as a cathode load for the amplifier, means also connecting said resistor in series with the D. C. armature circuit of said motor, a pair of relays for controlling the closure of said armature circuit and for controlling the direction of current flow through said armature, said relays maintaining said armature circuit open except when a predetermined minimum current flows in the output circuit of said amplifier.

6. An automatic follow-up system for a device to be automatically set in different positions, comprising a follow-up motor for operating said device, a source of control voltage, means to derive from said source a follow-up voltage of variable amplitude, means to derive from said source another control voltage of uniform amplitude, an electron tube network upon which both said control voltages are impressed to derive a resultant whose magnitude and polarity

correspond to the extent to which the motor is to be operated and to its required direction of operation, said network comprising at least one grid-controlled tube amplifier, a pair of relays for controlling the supply of D. C. current to said motor, said relays being selectively responsive to the polarity of said resultant, and means controlled by said relays for varying the gain of said amplifier, the last-mentioned means including a cathode load resistor for said amplifier, the current through said load resistor being composed in part of the plate-to-cathode current of said amplifier tube and of the motor current.

7. An automatic follow-up system according to claim 6 in which the gain of said amplifier is adjusted in accordance with said follow-up voltage and said D. C. motor current so that for large values of follow-up voltage the said relays are maintained operated to cause the said motor to operate at full speed, and as the follow-up voltage becomes smaller the said relays alternately open and close to cause the said motor to operate in a rapid series of incremental steps.

8. An automatic follow-up system according to claim 6 in which said relays are connected to said resistor to decrease the gain of said amplifier for large magnitudes of said follow-up voltage, and to increase the gain for follow-up voltages below a predetermined minimum.

9. An automatic follow-up system for a device to be automatically set in different positions, comprising a follow-up motor of the reversible D. C. type, a pair of electromagnetic relays for opening and closing the D. C. supply circuit of said motor and for controlling the polarity of current flow through the motor armature, a pair of grid-controlled relay tubes for selectively controlling said relays, a source of alternating current, means to derive from said source a follow-up signal which is proportional to the extent to which said device is to be moved from one setting to another setting, means including a grid-controlled amplifier tube to apply said follow-up signal in opposite phases respectively to the grids of said relay tubes, means to apply in like phase to said grids a signal of uniform amplitude from said alternating current source, said electromagnetic relays having their windings connected in divided balanced relation in the respective output circuits of said relay tubes, gain control means for said amplifier, means to energize said gain control means jointly by the plate-to-cathode current thereof and by the armature current of said motor.

10. An anti-hunting arrangement for automatic follow-up systems and the like, comprising a follow-up motor, a source of alternating control current, means to derive from said source an alternating current follow-up signal, a pair of grid-controlled electron tubes, means to apply the follow-up signal in balanced opposed phase to the grids of said tubes, means to apply to the said grids in like phase an alternating current signal of uniform amplitude from said source, a pair of relays having their windings connected in divided balanced relation in the output circuits of said tubes, a D. C. power circuit for the armature of said motor and controlled by said relays, a grid-controlled amplifier for said follow-up signals, control means for controlling the sensitivity of said amplifier, and means to energize said gain control means by the armature currents of said motor and by the plate cathode current of the amplifier.

11. An anti-hunting arrangement for follow-

up systems and the like, comprising a variable speed D. C. reversible follow-up motor, a source of follow-up signals, an amplifier for said signals, a motor power supply circuit, means to continuously apply said signals to close said motor power supply circuit to rotate said motor at relatively high continuous speed for large values of follow-up voltage and automatically to open the motor circuit when the follow-up voltage drops below a predetermined level, and means to open and close said motor circuit in rapidly successive steps as said follow-up voltage approaches zero from said predetermined level, the last-mentioned means including a resistor which is connected in common to the motor supply circuit and to the cathode return circuit of said amplifier to control the sensitivity of said amplifier in accordance with the levels of said follow-up voltage.

12. An anti-hunting arrangement according to claim 11 in which the last-mentioned means includes a grid-controlled amplifier tube and a pair of relays, said relays having contacts for connecting a cathode load gain control resistor for said amplifier tube in series with the armature of the motor.

13. An automatic follow-up system for a device to be automatically positioned, comprising a follow-up motor for operating the device, an energizing circuit for applying operating current to said motor, means to develop a follow-up voltage whose magnitude corresponds to the extent to which the device is to be moved from one setting to another, an amplifier for said follow-up voltage, gain control means for said amplifier for controlling the sensitivity thereof, means controlled by said amplifier follow-up voltage to open and close said motor energizing circuit, and means to energize said gain control means jointly by the follow-up voltage impressed upon said amplifier and by the said motor operating current to bring said device to said other setting by maintaining the motor energizing circuit continuously closed for large magnitudes of follow-up voltage while rapidly opening and closing the motor circuit for low values of follow-up voltage.

14. Apparatus for controlling a follow-up motor for a remotely controlled device, comprising a source of follow-up signals, an amplifier for said signals said amplifier having a cathode load element, a power supply circuit for said motor, and means connecting said load element common to the amplifier and motor power circuit for controlling the sensitivity of the amplifier in accordance with the level of the follow-up signals applied to the input of said amplifier and in accordance with the power current flowing through the motor.

FRANCIS L. MOSELEY.

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