Feb. 22, 1949. C. T. SCULLY 2,462,134

REMOTE CONTROL ARRANGEMENTS

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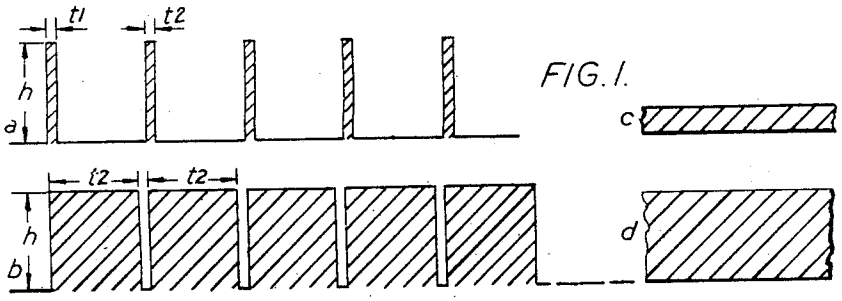


FIG. 1.

FIG. 3.

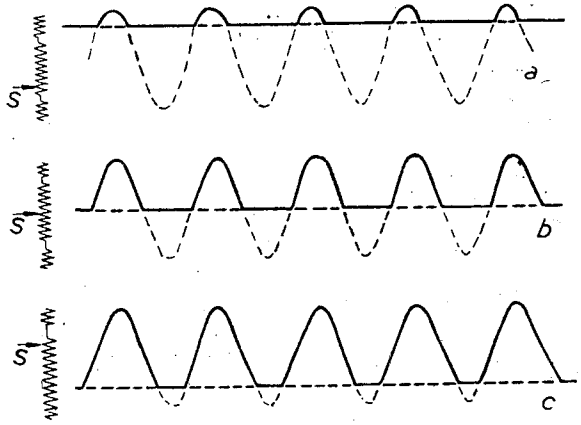


FIG. 4.

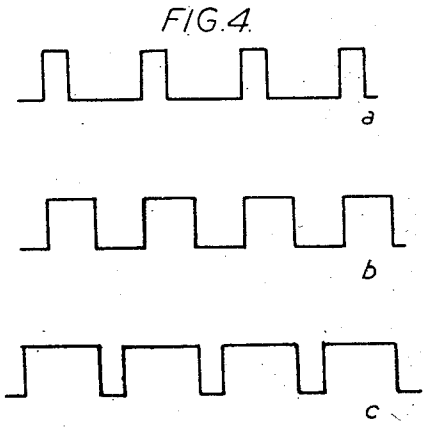
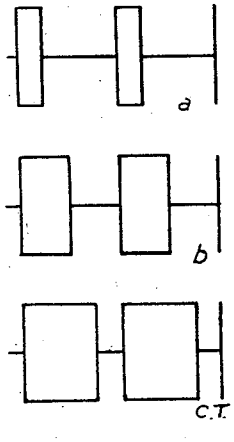


FIG. 5.



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FIG. 2.

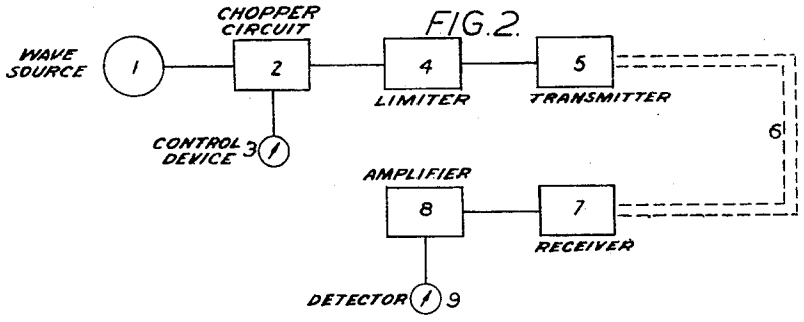


FIG. 8

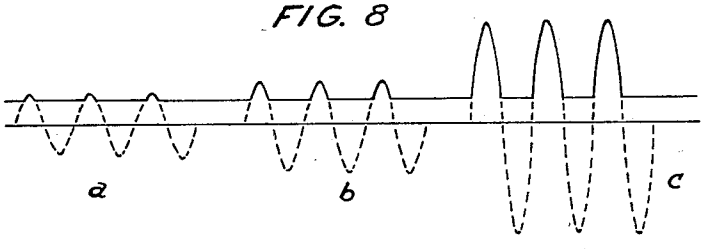
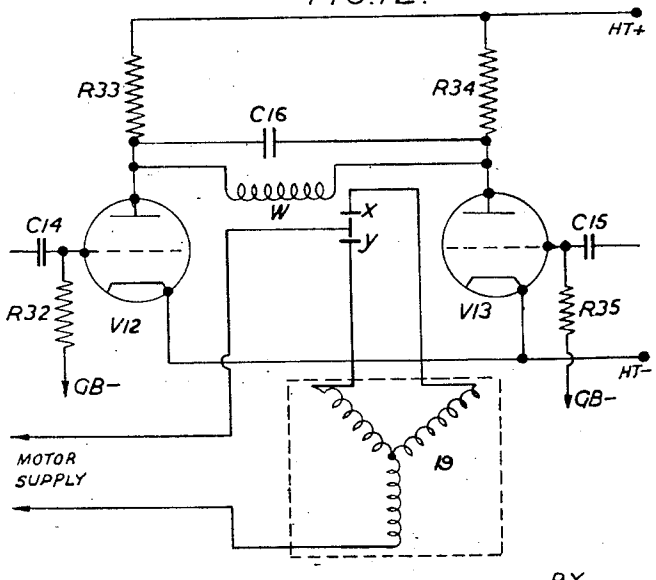


FIG. 12.



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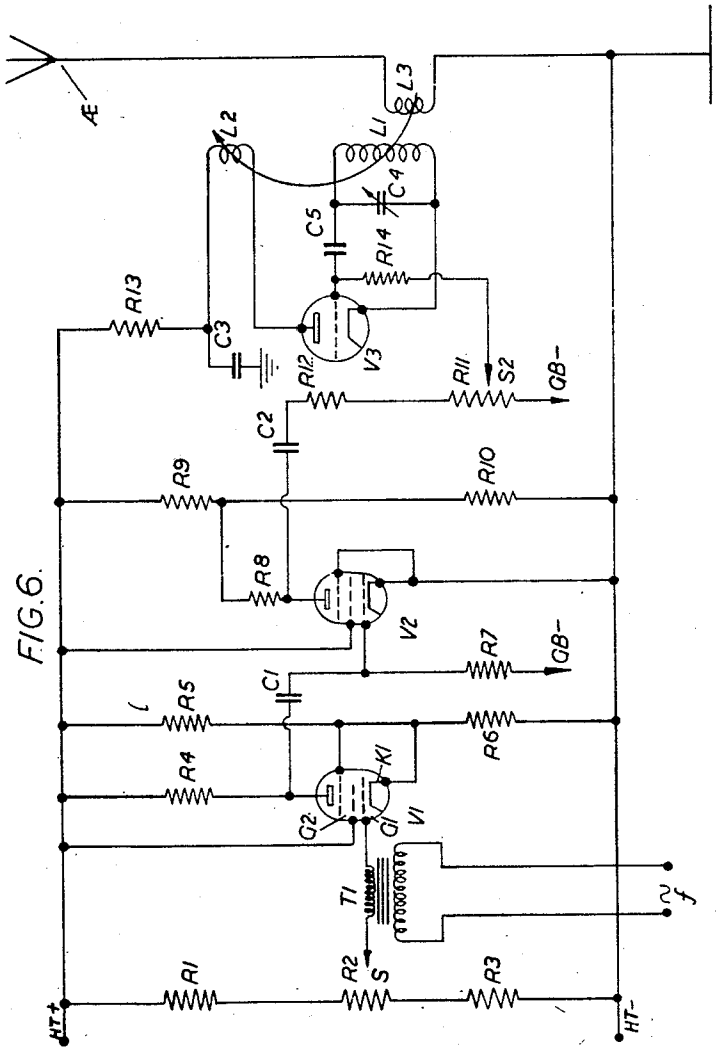


FIG. 6.

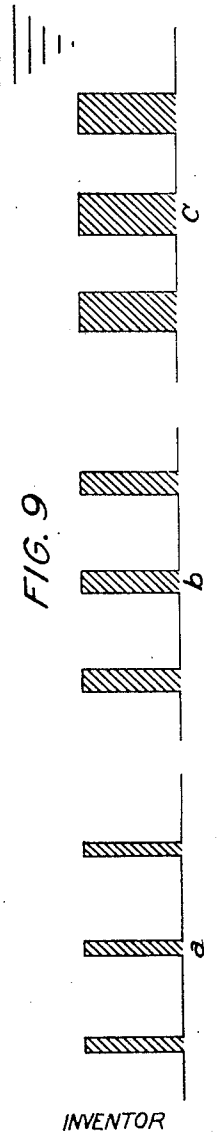


FIG. 9.

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REMOTE CONTROL ARRANGEMENTS

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FIG. 7.

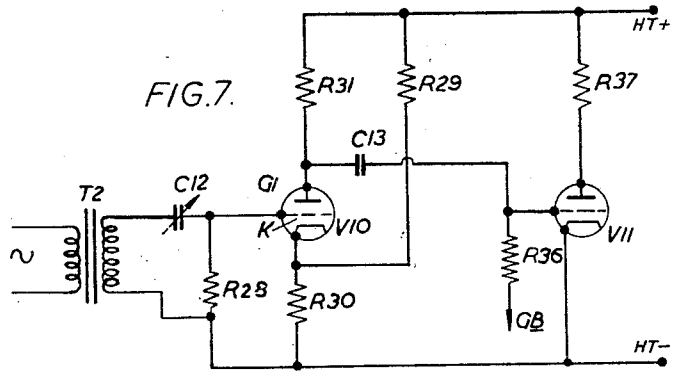


FIG. 10.

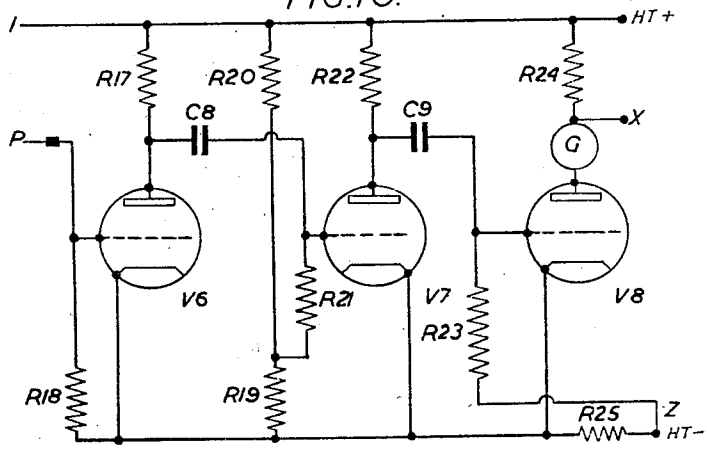
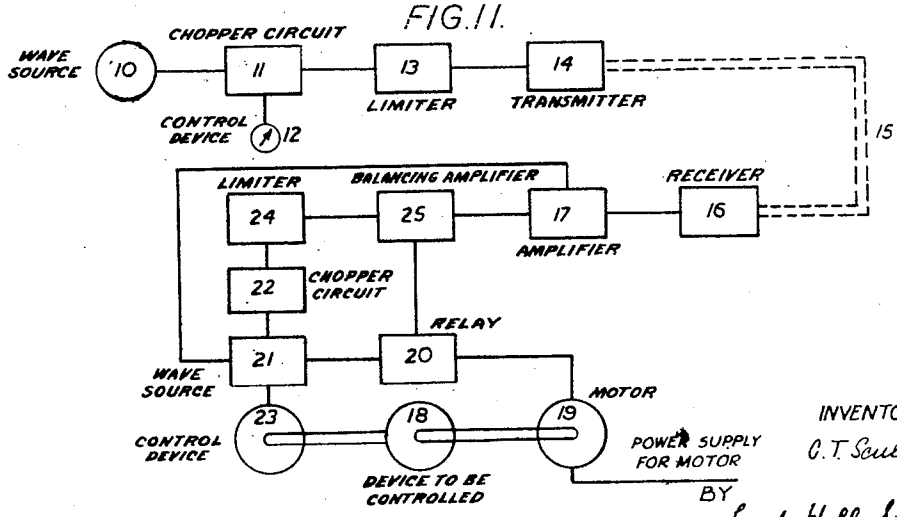


FIG. 11.



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UNITED STATES PATENT OFFICE

2,462,134

REMOTE CONTROL ARRANGEMENT

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Application October 14, 1942, Serial No. 462,024
In Great Britain September 30, 1941

Section 1, Public Law 690, August 8, 1946
Patent expires September 30, 1961

9 Claims. (Cl. 318—18)

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The present invention relates to remote control arrangements and according thereto time modulated pulses are transmitted from the controlling end to effect a desired operation at the remote controlled end. By time modulated pulses is meant that the pulses are transmitted at equal intervals of time, that is the pulse frequency in constant, but the duration of the pulses is varied.

According to an embodiment of the invention, remote control arrangements for giving at the remote end an indication of a measuring instrument located at the controlling end, are characterised in this that the measuring instrument is arranged to control the pulse duration of a series of electrical pulses in accordance with the value of the measure obtained by said instrument, and at the remote end, the said pulses are used to produce a current or voltage proportional to the pulse duration said current or voltage being applied to give the desired indication.

According to another embodiment of the invention, remote control arrangements for operating a device at the remote controlled end to a position predetermined at the controlling end is characterised in this that a series of pulses of pulse duration in accordance with said predetermined position is transmitted and at the remote end said pulses are used to produce a current or voltage for controlling a motor for operating said device.

In carrying the invention into practice, the time modulated electrical pulses are integrated over a period of time and the average or mean direct current thus produced is employed to effect the desired operation or indication.

The invention will be better understood from the following description of the two embodiments referred to above, taken in conjunction with the accompanying drawings in which:

Fig. 1 are graphs explanatory of the principle on which the invention is based;

Fig. 2 shows in block schematic the arrangements of the first embodiment hereinbefore referred to;

Figs. 3, 4, 5 are curves explanatory of the arrangement shown in Fig. 2;

Fig. 6 shows the circuit arrangements of the controlling end of the arrangement shown in Fig. 2;

Fig. 7 shows alternative circuit arrangements of a "chopper" stage;

Figs. 8 and 9 are curves explanatory of the arrangement shown in Fig. 7;

Fig. 10 is the circuit arrangements of an amplifier suitable for use at the controlled end;

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Fig. 11 is a block schematic of another embodiment of the invention in which the power required to operate a device at the remote end is large; and

Fig. 12 shows the circuit details of one of the units of Fig. 11.

In the wave form diagrams of Figs. 1, 3, 4, 5, 8 and 9 the abscissae represent time and the ordinates instantaneous wave amplitude.

Referring to Fig. 1, *a* and *b* represent two series of pulses of equal pulse frequency but of different pulse durations. In *a* the pulses are of short duration *t1* and give an average or mean direct current whose level is represented by the ordinate of *c*. In *b* the pulses are of long duration *t2* and give a much stronger mean or average direct current whose level is represented by the ordinate of *d*. It will be observed from this that the width or duration of the pulses and consequently the mean level can be varied between any two such limits as *t1*, *t2* the ordinates of *c* and *d*.

If an alternating voltage of suitable frequency (*f*) is fed to a non-linear circuit element, under certain conditions, a series of pulses of repetition frequency (*f*) will be obtained at the output of such an element and the time duration of such pulses can be varied by the alteration of the voltage across, or the electrical constants of, the non-linear element, either separately or together. Two or more stages may be necessary, the first of such stages is referred to hereinafter as a "chopper" stage and the subsequent stages as "limiter" stages. Thermionic valves or saturated inductances for instance can be used for the non-linear elements.

The advantages of the arrangements according to the invention are that the frequency band required to transmit the intelligence (i. e. an indication, or a required operation to be performed at the controlled end) from the controlling to the controlled end can be made small and provide, by means shown hereinafter, a simple and reliable arrangement of rendering the intelligence transmitted to a large degree independent of the variations of the received signal, for example by providing ample amplification of the received signal followed by a limiter stage. The controlling and controlled apparatus in a system according to the invention are continuously variable between two pre-arranged or otherwise fixed limits and does not function in discrete steps. Any known system of pulse modulation can be used for transmitting the intelligence and the advantages claimed for pulse modulation in general, and for the system chosen in particular, with regard

to economy of power, freedom from interference and so on will be present in systems according to the present invention.

These pulse modulation systems are now well known and comprise the single pulse system, in which the pulses are of the type illustrated in Fig. 1, or the double pulse system, in which pulses of constant short duration are transmitted to mark the beginning and end of a full pulse as shown in Fig. 1. In the double pulse system one of the pulses of short duration occurs at equal intervals of time and this pulse may be suppressed at the transmitter and reinstated at the receiver. Another pulse system called the L pulse system is a combination of this modified double pulse system and the single pulse system and transmits pulses of L shaped waveform, the short pulse of constant duration having a greater amplitude than the single time modulated pulse with which it is combined and may occur at the beginning or end of the single time modulated pulse. This pulse of constant duration occurs at varying times and at the receiver is separated from the single time modulated pulse and combined with a pulse of short constant duration occurring at equal intervals of time. At the receiver the two short pulses are utilised to produce a mean current which is utilised for the purposes of the present invention. Methods of generating and modulating these types of pulses are disclosed in United States Patent No. 2,256,336, September 16, 1941, and 2,298,922, October 13, 1942.

Reference will now be made to Fig. 2 of the drawings which shows a block schematic of an arrangement according to the invention in which the power required to operate the device at the remote end can be obtained directly from a thermionic valve, for instance when the indication of an instrument located at the controlling end is required to be given at the remote end on another indicating instrument.

In this embodiment, the time modulation of the pulses is controlled by the instrument whose indication is required to be given at the remote end, and a suitable detector of voltage or current is connected to the receiver at the remote end, and this detector may be calibrated to give an accurate repetition of operation of the controlling instrument.

In Fig. 2, a source 1 of alternating voltage of frequency (*f*) is connected to a "chopper" circuit 2 which can be varied by a control 3 as explained hereinafter. The chopped wave is passed to a limiting amplifier 4 which changes the chopped waveforms shown in Fig. 3 to pulses of the required shape shown in Fig. 4. The time modulation of these pulses is characteristic of the particular position of control 3.

The output of amplifier 4 is connected through a transmitter 5 described more in detail hereinafter and a link radio or cable 6 to an appropriate receiver 7 and an amplifier 8. A detector 9 of current or voltage connected to amplifier 8 and suitably calibrated gives the indication required at the remote end.

Referring now to the circuit shown in Fig. 6, a valve V1 and its associated circuits form the "chopper" circuit 2 (Fig. 2). It is fed at its grid G1 with an alternating voltage of frequency (*f*) from the secondary of transformer T1, this being the source represented at 1 Fig. 2. The other terminal of this secondary is connected to the slider S of the potentiometer R2 being part of resistance chain R1, R2 and R3, connected in series across the H. T. supply. R2 is the control represented

at 3 Fig. 2. Since the cathode K1 of V1 is held positive with respect of the H. T. negative line by the resistance chain R5, R6 connected in series across the H. T. supply, the grid G1 of V1 can be either positive or negative with respect to its cathode K1, depending on the particular position of the slider S on the potentiometer R2. This voltage is impressed on the grid via the secondary of transformer T1. Thus the duration of the current flow in the resistance R4 which is the anode load of valve V1, is governed by the position of slider S. The action of the circuit is illustrated graphically in Fig. 3, curves *a*, *b* and *c*, the full line indicating the shape of the voltage obtained across R4 with the control S in the three successive relative positions shown on the left hand side. A valve V2 with its associated circuit is arranged to act as the amplifying and limiting circuit corresponding to 4, Fig. 2, and curves *a*, *b* and *c*, Fig. 4, show the wave shapes of the voltages developed across resistance R8 in the output of V2 for the same successive positions of the control S, R8 being part or whole of the anode load of V2.

This voltage obtained across R8 is transmitted to the receiver at the remote end by any known means, for example by radio or cable, in particular it may be used to modulate an oscillator such as V3 (Fig. 6) working at any suitable predetermined carrier frequency and forming with its associated circuit the transmitter 5 (Fig. 2). The curves *a*, *b* and *c*, Fig. 5, show the type of signals transmitted corresponding to the successive positions of the control S as in the previous Figs. 3 and 4.

The intervalve coupling between V1 and V2 comprises the capacity C1 and resistance R7 and the intervalve coupling between V2 and V3 comprises the capacity C2 and series connected resistances R11 and R12. Negative grid bias is applied to V2 and V3 from GB. The valve V3 and its associated circuits consisting of the tuned grid-cathode circuit C4L1 coupled to the grid by capacity C5 and inductively to the regenerative feedback coil L2 in the anode circuit by coil L1 forms the carrier frequency oscillation generator, whose amplitude of the oscillations is modulated by the pulse output from V2. The inductance L2 in the output of valve V3 is coupled also to the inductance L3 in the circuit of the antenna AE to feed the antenna. The depth of the modulation is adjusted by means of a variable tap S2 on resistance R11, and the modulating potentials from S2 are applied to the grid of V3 over resistance R14. A load resistance R13 is included in the anode circuit of V3 and is connected at its anode end to earth over capacity C3.

Fig. 7 indicates another circuit arrangement for obtaining the "chopping" of the source 1 (Fig. 2), by means of valve V10 corresponding to V1, Fig. 6. In this arrangement the A. C. voltage is varied whilst the D. C. voltage on the valve is kept constant. This arrangement is to be preferred as it eliminates the sliding contact S, Fig 6, and uses a variable condenser C12, Fig. 7, for the control represented at 3, Fig. 2.

Operation of the circuit shown in Fig. 7 will be understood from the following explanation. The transformer T2 feeds the resistance capacity network C12–R28 which is in series across its secondary with an alternating voltage of any suitable frequency (*f*). The grid G1 of V10 is connected to the junction of C12, R28, whilst the cathode K of V10 is held positive with respect to the H. T. negative or earth line by the resistance

chain R29, R30 connected across the H. T. supply. The grid of V10 is then negative to its cathode by the D. C. voltage (*d*) developed across R30. Variation of the capacity of the condenser C12 causes the amplitude of the alternating voltage (A) across R28 to vary and by suitably proportioning the two voltages (A) and (*d*) applied to the grid of V10, the duration of the pulse of current through R31 which is the anode load of V10 can be made to vary with and be characteristic of the variation of capacity of C12.

V10 is coupled by a condenser C13 and resistance R36 to the grid of a valve V11 which with its associated circuit functions as an amplifier and limiter as does V2 in Fig. 6. R37 is the load resistance in the anode circuit of V11.

The action of the circuit is illustrated graphically in Figs. 8 and 9, *a*, *b* and *c* showing the voltage waveforms developed across R31 for three particular positions of control varying capacity of C12. These correspond to the waveforms shown in Figs. 3 and 4, at *a*, *b* and *c*, respectively.

Fig. 10 is a circuit suitable for the amplifier 8, Fig. 2, and the thermionic valves V6, V7, V8 and their associated circuits comprise a three stage cascade amplifier resistance-capacity coupled at C8, R21, and C9, R23, respectively, the number of stages required depending on the amount of variation of received signal it is required to tolerate in practice, so as to provide ample amplification to give a steady output in the limiter stage which follows the amplifier. The amplifier is simple and the anode circuits do not require decoupling as when in use with other types of signal. Provision should be made as shown for the bias voltage of alternate valves to be negative to the anode current cut-off point or beyond, e. g. V6 and V8, and positive to anode current saturation point, e. g. V7, the values of anode load R22 and/or H. T. voltage being chosen so that the valve is not over-run in the latter case. R17 and R24 are the anode loads respectively of V6 and V8. The bias must remain substantially constant irrespective of the duration of the pulse or train of pulses being amplified, hence either bias battery or potentiometer supply is used.

If a voltmeter of suitable range is connected between X and Z or a galvanometer G be inserted in the anode of V8, it may be calibrated to indicate the position of slider S, Fig. 6, or the setting of condenser C12 as at the transmitter, Fig. 7. This slider or setting may be controlled by the instruments whose indication is to be transmitted, for instance by a mechanical coupling in any well known manner.

Fig. 11 shows a block schematic of another embodiment of the invention in which the power required for producing a desired operation at the remote end is large. In such a case, it is more convenient to use contactors or relays to switch local power for the operation at the remote end; for example, when it is desired to move some relatively heavy object in some sense to a predetermined position.

If from the controlling end, a series of pulses is transmitted the duration of the pulses being characteristic of the position the device at the remote end is required to take up, a pulse or series of pulses can be compared with a similar pulse or series of pulses generated at the receiver at the remote end and whose pulse duration is characteristic of the actual position of said device. Any difference between the values of the received and generated pulses or mean values thereof may be used to move the device to the desired position.

The units 10 to 17 correspond to units 1 to 8 respectively of Fig. 2. Unit 9 is not used in the case of Fig. 11 and there is in addition the device 18 at the remote end, the motor 19 to operate 18 and a relay or contactor system 20 which controls the motor. A source of current 21 corresponding to 1 (Fig. 2) is fed to a chopper circuit 22 corresponding to 2 (Fig. 2), and is varied by control 23 corresponding to 3 (Fig. 2). Control 23 is linked to device 18 by any known means. The output from 22 is fed to a limiting amplifier 24 corresponding to 4 (Fig. 2), hence the time modulation or average value of the output from 24 is characteristic of the position of 18. Detail circuits for the units 22 and 24 have already been described in relation to Figs. 6, 7 and 8 of the accompanying drawings.

The output from 24, together with the output from 17 are fed into balancing amplifier 25 and their difference obtained. This difference reverses in sign or becomes zero according to whether the output from 17 is greater than, less than, or equal to the output from the amplifier 24. It is amplified by the circuit 25 if not zero, and the output from 25 operates a relay system 20 causing the motor 19 to rotate moving the device 18 and the control 23 in such a sense that the voltage difference across 25 tend to become zero.

The source 21 of alternating current may be a sawtooth oscillator synchronised to the output of amplifier 17 by any known means. The other input for the balancing amplifier 25 is obtained as before by a control 23 of the tunable circuit type described in reference to Figure 7 a "chopper" circuit 22 and an amplifier 24.

Fig. 12 shows circuit details of the balancing amplifier 25. The valve V12 is suitably biased via a grid leak R32 and the output of 24, Fig. 11 is fed to its grid via a condenser C14. The valve V13 is suitably biassed via a grid leak R35 and the output of amplifier 17 Fig. 11 is fed to its grid via condenser C15. The waveforms of current in anode load resistances R33 and R34 will be equal if the time modulation of the waveforms from 17 and 24 are equal or provided their average values over a short period of time are equal. The length of this period is governed by the time constant R33, R34, C16. The energising winding W of a polarised centre zero relay with two sets of contacts *x* and *y* is bridged across R33 and R34, hence if the received signal is changed in time modulation in such a sense that the output from 17 causes the voltage across R34 to rise current flows through the relay from R33 and R34 and closes set of contacts, say *x*, and the motor 19 is caused to run in such a sense to alter the time modulation of the output of 24 by means of control 23 until the voltage across R33 is also increased by a like amount and voltage balance is restored. The relay then returns to its centre position and switches off the motor 19.

When the time modulation alters in such a sense that the voltage across R34 is reduced, the relay moves in the opposite sense and closes contacts *y* causing the motor 19 to rotate in the opposite sense to the former case, the time modulation of 24 and the voltage across R33 also to move in the opposite sense so restoring the voltage balance and causing the relay to switch off the motor 19.

The remote device is also moved as required by motor 19, and this is caused to run in either direction, until the local source 24 balances the

time modulation of the received signal, hence device 18 is controlled by this time modulation and therefore by controls 12 and 13 at the transmitter end.

Whilst a polarised relay has been referred to, it will be understood that any other type of relay, for example, thermionic relays, may be used and the modifications necessary to the circuit described will be clear without further description to those skilled in the art.

Whilst two specific embodiments of the invention have been described by way of example it will be understood that other embodiments will be apparent to those skilled in the art and all of which come within the scope of the appended claims. Particularly, it will be understood that whilst the embodiments described have utilised single time modulated pulses for conveying the intelligence, the double pulse, or modified double pulse systems, or the L-pulse system of intelligence transmission may be utilised.

What is claimed is:

1. An electrical remote control system, comprising first and second stations and a transmitting medium extending therebetween, means at said first station for generating electrical pulses time modulated in accordance with the control to be effected at the second station, comprising a source of oscillations of given frequency, an electron discharge device having a grid, means for coupling said source of oscillations to said grid, means for biassing said grid for operation only in response to positive half waves from said source, said coupling means including a capacitor adjustable in accordance with the remote control to be effected, at the second station an electric motor for effecting the desired control, means for receiving from the transmitting medium the time modulated pulses, a source of locally generated pulses with synchronizing connection to the time modulated pulses received to have a repetitive rate at said given frequency, means for modulating said locally generated pulses in accordance with the condition of the apparatus to be controlled, said modulating means being similar to the modulating means at the first station and including a variable capacitor with means connecting the same to the controlled device, means for comparing the received modulated pulses and means for controlling thereby said motor.

2. A transmitter for an electrical remote control system comprising a source of oscillations of given frequency, a first thermionic valve having a cathode, an anode, and a control grid, means to apply said oscillations to said control grid, means to bias said control grid so that said valve will operate for positive portions only of said oscillation, further means for potential biassing said grid toward operation comprising a resistance connected between the cathode and grid, and means for changing its effective value in accordance with the value of the remote control to be effected, a limiting valve having a cathode, a control grid, and an anode, means to apply the output of said first valve between the control grid and cathode of said second valve, an antenna system, a transmitter coupled to said antenna system, and means to couple the anode and cathode of said second valve to said transmitter.

3. A transmitting apparatus for a remote control system in accordance with claim 2, in which the means for changing the effective value of the resistance of said further grid bias of the first valve includes means supplying a voltage across said resistance from said oscillations.

4. A transmitter apparatus for a remote control system in accordance with claim 2, in which the means for changing the effective value of the resistance includes a resonant circuit coupling said source across said resistance and having an impedance adjustable for varying its frequency about the frequency of said source, and means for adjusting said impedance in accordance with the desired control.

5. A transmitting apparatus for a remote control system in accordance with claim 2, in which the means for changing the effective value of the resistance of said further grid biassing of the first valve includes a coupling circuit between the source of said oscillations and said grid having a series capacitor, said coupling circuit being bridged across said resistance.

6. A transmitting apparatus for a remote control system in accordance with claim 2, in which the means for changing the effective value of the resistance of said further grid bias of the first valve includes a coupling circuit between the source of said oscillations and said grid having a series capacitor, said coupling circuit being bridged across said resistance, and said capacitor being variable in accordance with the control to be remotely effected.

7. A transmitting apparatus for an electrical remote control system in accordance with claim 2, in which the amplitude of the oscillation delivered to the first valve is maintained constant and the effective value of the resistance of the said further grid bias of said first valve is adjusted directly in accordance with the control to be effected.

8. An electrical remote control system comprising first and second stations and a transmission medium extending therebetween, means at said first station for generating electrical pulses repetitive at a given frequency, means at said first station for time modulating said pulses in accordance with a desired control to be effected at said second station, means at said first station impressing said time modulated pulses on said transmission medium, at said second station means for receiving said time modulated pulses, a device to be controlled and controlling means therefore comprising an energy balancing means for controlling said device, local pulse generating means time modulated in accordance with the controlled condition of said device for supplying a component of energy to the balancing means, connections for deriving from the received pulses both another component of energy for the balancing means and a control for synchronizing the local pulse generator with the pulse repetitive rate of the transmitter, the connection for deriving said second mentioned component from said received pulses including a limiting amplifier comprising a plurality of thermionic valve amplifier stages with resistance-capacity inter-stage couplings, the grid bias voltage on alternate stages being negative with respect to the anode-current cut-off point and positive with respect to the anode-current saturation point.

9. An electrical remote control system comprising first and second stations and a transmission medium extending therebetween, means comprising an electron discharge device at said first station for generating electrical pulses repetitive at a given frequency, means at said first station for time modulating said pulses in accordance with a desired control to be effected

at said second station, means at said first station for impressing said time modulated pulses on said transmission medium, an electric motor for effecting said desired control at said second station, at said second station means comprising an electron discharge device for receiving said time modulated pulses, a source of locally generated pulses with synchronizing connection to the time modulated pulses received to have a repetitive rate at said given frequency, means for modulating said locally generated pulses in accordance with the condition of the apparatus to be controlled, means for comparing the received modulated pulses and the locally generated modulated pulses, means for utilizing the resultant component to control said motor, said means for comparing the received modulated pulses and the locally generated modulated pulses comprising a balancing thermionic amplifier including two three-electrode thermionic valves having parallel anode circuits, and means for applying said two sets of pulses to the respective grids of said valves.

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