Feb. 26, 1946. H. V. ALEXANDERSSON ET AL 2,395,708

REMOTE CONTROL SYSTEM

Filed May 8, 1940 4 Sheets-Sheet 1

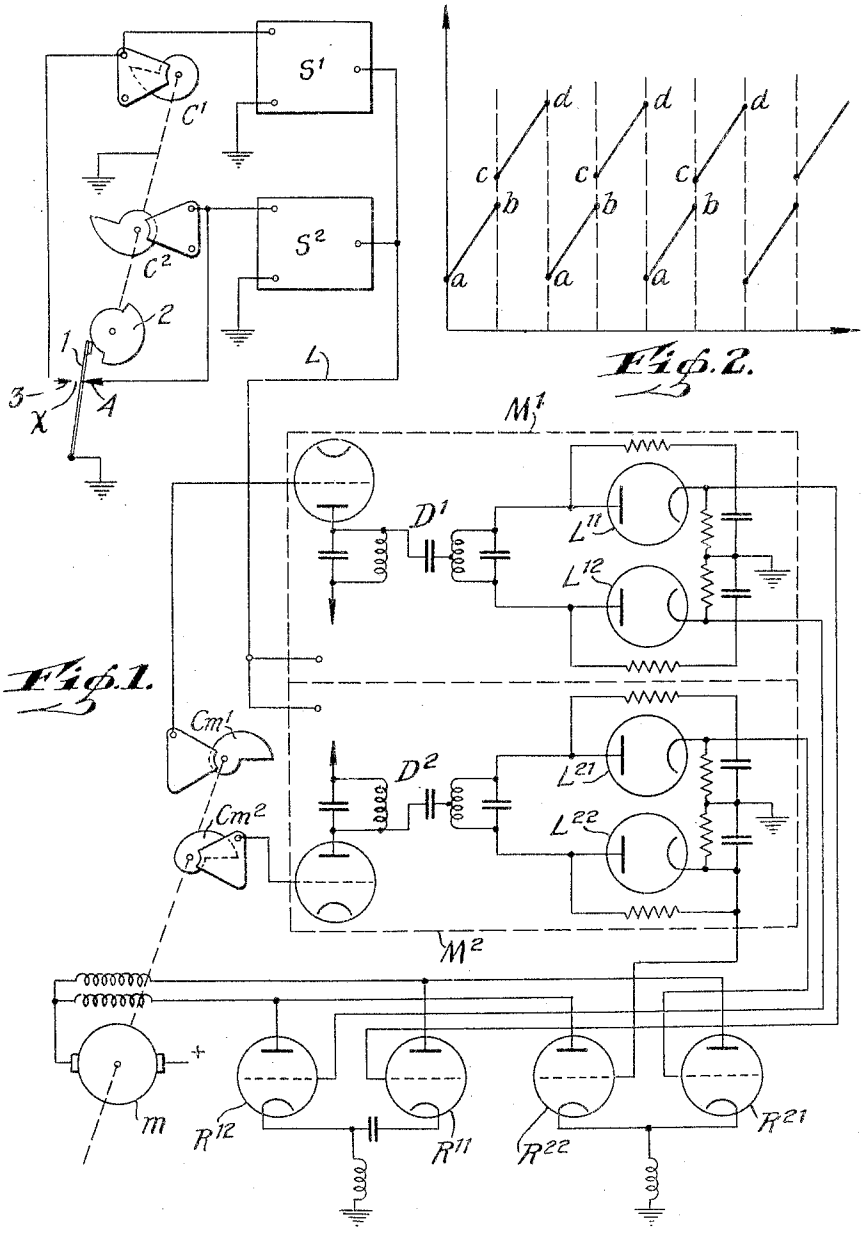


Fig. 1.

Fig. 2.

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REMOTE CONTROL SYSTEM

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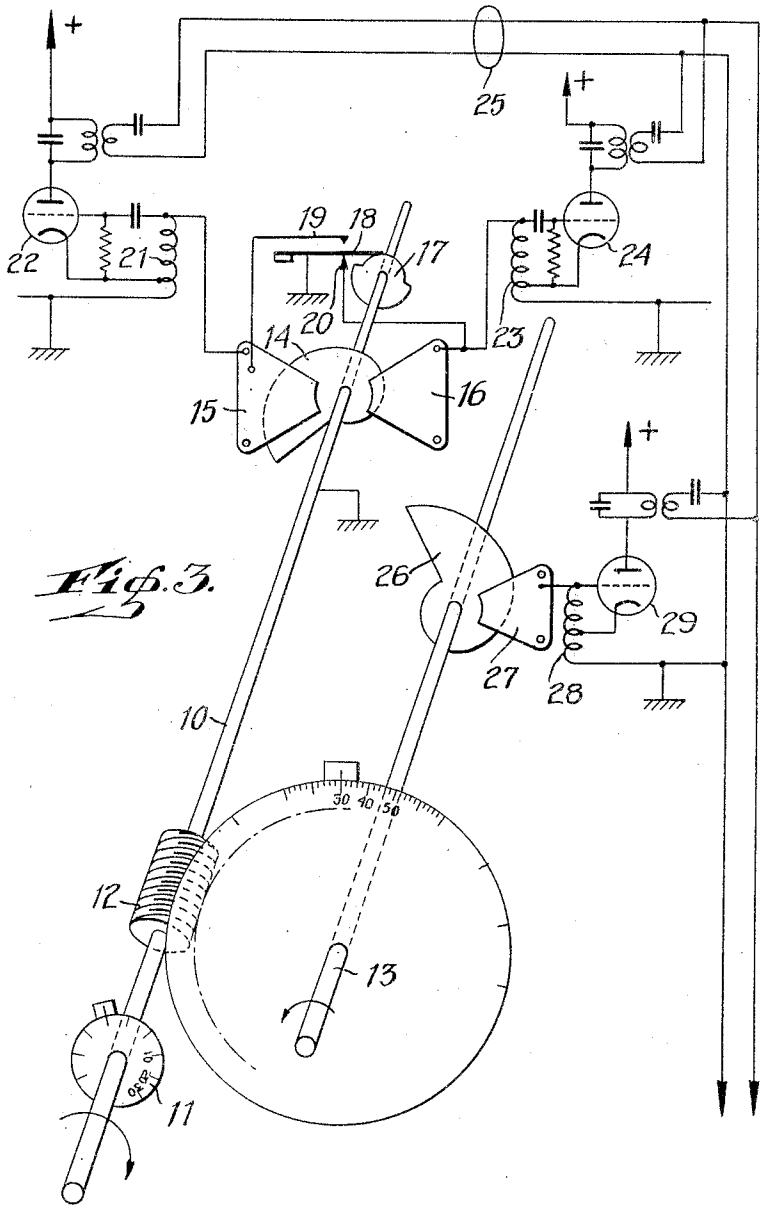


Fig. 3.

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REMOTE CONTROL SYSTEM

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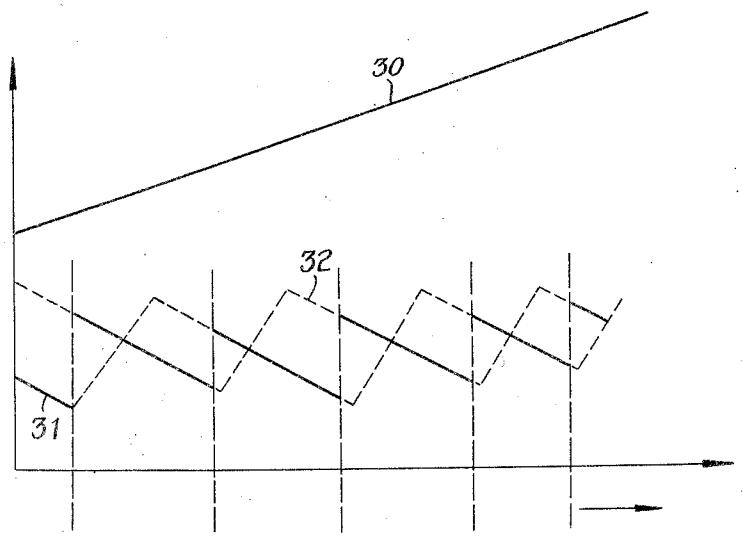


Fig. 4.

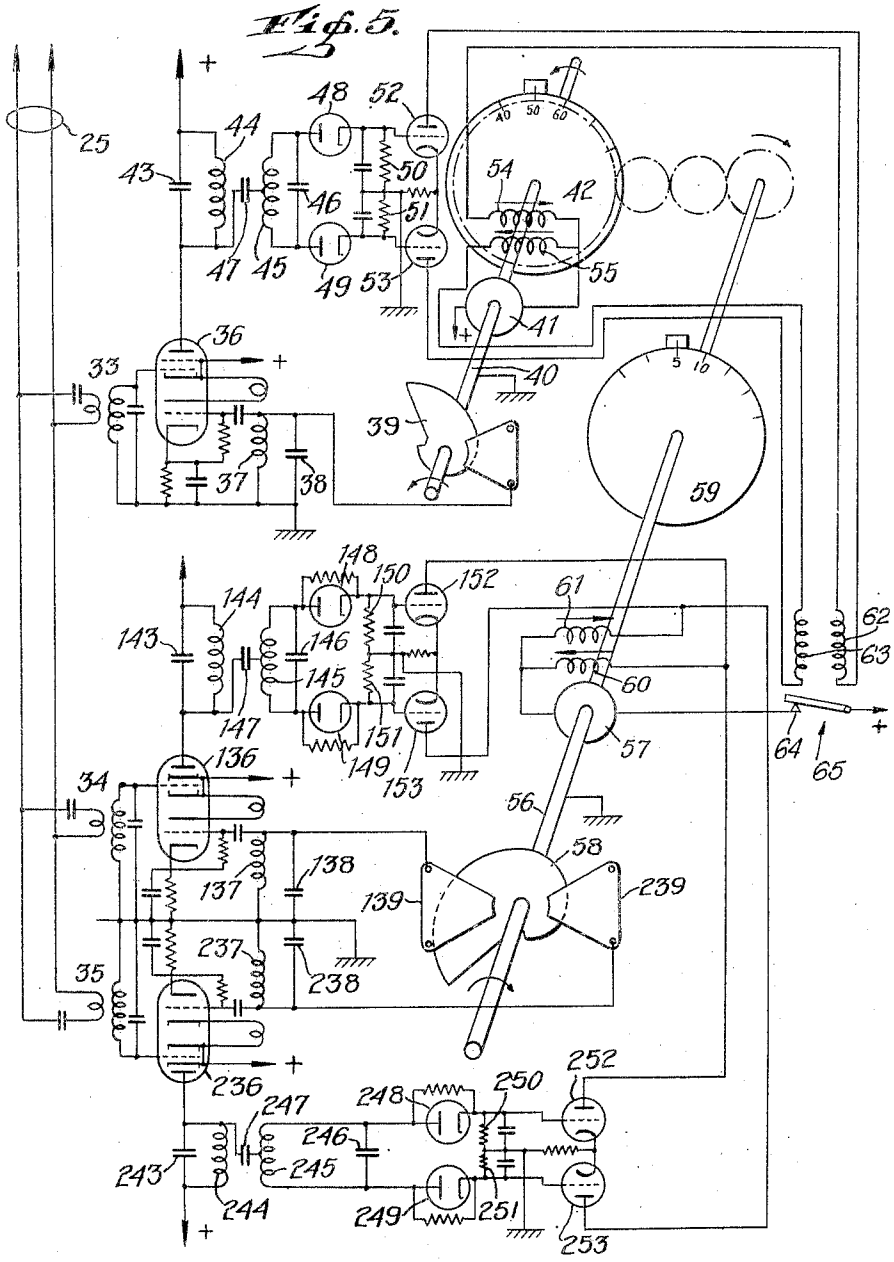
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Fig. 5.



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Patented Feb. 26, 1946

2,395,708

UNITED STATES PATENT OFFICE

2,395,708

REMOTE CONTROL SYSTEM

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Application May 8, 1940, Serial No. 333,926
In Sweden May 24, 1939

14 Claims. (Cl. 172—239)

In remote control systems of the variable frequency type in which the transmitted frequency is a function of the position of an object at the transmitter, and in which the receiver contains a frequency-meter or other similar device which takes a position dependent upon the received frequency, there is difficulty in obtaining sufficient precision, particularly in cases where a large angular movement is to be transmitted. In remote control systems of this type, the object at the transmitter, the angular movement of which is to be reproduced at a remote position, is connected to a means to control the frequency transmitted which may, for example, be a frequency of the order of radio frequencies.

The receiver is provided with means selective for frequencies of different ranges, which, in the simplest case, may constitute frequency-meters. An improved form of receiver includes an oscillator together with a tuning circuit the tuning means of which is controlled by a motor which also drives the controlled object. A discriminator is provided for comparing the received frequency with the oscillator frequency generated in the receiver and the motor is connected to tune the oscillator frequency to a value which is a function of the received frequency.

As frequency determining means, simple oscillation circuits may be used. However, these have only a limited frequency range which must cover the entire range of movement of the transmitter object. On the other hand, the precision of the system is determined by the frequency discriminating power of the receiver, which cannot be made too sharp without risk of over-control and hunting and without risk that the control will be unable to follow if there is too great a lag between the transmitter and the receiver. Hence, the precision is reduced as the range of movement of the transmitter object increases.

Within certain fields, especially within the artillery art, it may be necessary to transmit angles up to 360°, or even up to a multiple of 360° with high precision. In such cases the precision usually becomes too small. The precision can be increased, however, by causing the receiver object to rotate a plurality of times, but this involves certain disadvantages which make such an arrangement impractical. Assume for instance, that the receiver organ is a standard frequency-meter. During 360° rotation of the transmitter object the frequency-meter will, provided it is used in the best possible way, sweep over its entire scale. If the transmitter object rotates a further 360°, thereby repeating the same frequencies, the frequency-meter must again be brought into its initial position, a problem which is rather difficult to solve, if the frequency-meter is also used as driving means for the receiver object. During the overlapping movement in question there is such unreliability in the coincidence between the transmitter and the receiver, that the operation of the receiver may be very inaccurate.

Furthermore, there is also a risk of error in that it is never certain that the transmitter object and the receiver object have passed through the same number of revolutions. If, for example, the receiver, for some reason, should become uncoupled while the transmitter rotates one or more turns, the receiver would, when again coupled in, show the correct angular position, but would not have made the correct number of turns and there would be no possibility of supervision unless the receiver were provided with an indicator to show the number of turns from its initial position.

The present invention relates to an arrangement for overcoming the above disadvantages. In accordance with the present invention the transmitter is arranged so as to sweep over a plurality of different frequency ranges, for instance, two frequency ranges which are separated from each other. In this way a more accurate and continuous control is maintained. The transmitter may include units responsive to the two frequency ranges which are operated respectively over alternate half revolutions of the transmitter object or the two units may operate simultaneously for fine adjustment and coarse adjustment respectively. In the latter case the fine adjustment unit will be connected to have a greater range of movement than the coarse adjustment unit.

In the following the invention is described with reference to the annexed drawings, in which Fig. 1 is a wiring diagram of a complete remote control arrangement according to the invention, Fig. 2 is a diagram for explanation of the operation of the arrangement according to Fig. 1, Fig. 3 is a wiring diagram of a modified form of the transmitter, Fig. 4 is a diagram, corresponding to the diagram of Fig. 2, for explanation of the operation of the transmitter of Fig. 3, and Fig. 5 shows diagrammatically a receiver to be used with the transmitter of Fig. 3.

The transmitter according to Fig. 1 contains two transmitting units S_1 and S_2 for transmitting radio frequency within different frequency

ranges. The tuning means for controlling the frequency of each of the transmitting units includes condensers C_1 and C_2, respectively. The two condensers are mounted on the same shaft as the transmitter object. The shaft also carries a cam 2 of a switch X, which includes a contact spring 1, arranged to be brought, by the cam 2, alternatively in contact with one or the other of two contacts 3 and 4. During the rotation of the shaft, therefore, the contacts 1—3 and the contacts 1—4 are alternately closed to connect the condenser C_1 and the condenser C_2 alternately into the oscillation circuits of the transmitters S_1 and S_2.

As will be apparent from the following explanation of the operation of the system, it is advantageous, if the contact arrangement is so made that one of the contacts is closed immediately before the other is opened and vice versa, so that the closing of the contacts will always overlap for a short time.

The two transmitting units S_1 and S_2 are connected in parallel by a common line L to the receiver, which consists of two superheterodyne units M_1 and M_2, so arranged that one of the receiver units M_1 has the same frequency range as one of the transmitting units S_1, and the other of the receiving units M_2 has the same frequency range as the other transmitting unit S_2. The receiving units are only schematically shown, as their construction has nothing to do with the present invention. Concerning the arrangement and operation of the receiver it is believed to be sufficient to mention the following:

Each of the receivers contains an oscillator, the tuning condensers of which C_{m1} and C_{m2}, respectively, are arranged on a common shaft, which also serves as the shaft of the controlled object. The control motor *m* is arranged on this same shaft. This motor is provided with two field windings, wound in such a way that the motor develops torque in one direction under the influence of one of the field windings and in the opposite direction under the influence of the other field winding.

In the intermediate frequency channel of each of the receiving units is arranged a frequency discriminator D_1 and D_2, respectively, of some suitable kind, which after rectifying the intermediate frequency, creates voltages which are a function of the displacement of the frequency in the intermediate frequency channel from the frequency to which the channel is tuned. Thus each of the discriminators contains two rectifiers L_{11} and L_{12} and L_{21} and L_{22}, respectively. The direct current voltages, obtained from the rectifiers, are amplified by means of the amplifier valves R_{11}, R_{12}, R_{21} and R_{22}, the valves R_{11} and R_{21} being connected in parallel to one of the field windings of the motor *m* and the two other of the amplifier valves being connected to the other of the two windings.

Due to the above described coupling arrangement, the superheterodyne receiving units, will convert the frequency received from the transmitting unit into an immediate frequency, preferably equal to the difference between the signal frequency of the transmitting unit and the internal oscillator frequency of the receiver, although the sum may be used. If the internal oscillatory frequency is correctly tuned, a frequency difference will be obtained which is exactly the same as the tuning frequency of the intermediate frequency channel, but if the oscillator frequency is wrong the intermediate frequency will be displaced in one direction or the other. Dependent upon the direction in which the intermediate frequency is displaced, there is obtained a stronger field current through one of the two field windings of the motor *m*, which causes the motor to rotate, and to turn the condensers of the receiver units in a direction to bring the intermediate frequency to the correct value where both of the fields in the motor are again in balance and the motor stops.

The operation of the arrangement as a whole is as follows:

It is assumed that the transmitting unit of the system is initially in the position shown in Fig. 1. The movement is further assumed to take place in clock-wise-direction. As apparent from the drawing this rotation of the cam closes the contacts 1—3 of the switch X and the condenser C_1 is coupled in, the transmitter unit S_1 therefor transmitting a frequency which varies with the position of the condenser during the rotational movement. The condenser is cut so that the capacity decreases when turned in clock-wise-direction, and therefor the frequency will increase, as shown in Fig. 2 by the curve *a*—*b*. This increase of frequency continues during a half revolution, and then the switch X uncouples the condenser C_1 and couples in the condenser C_2, so that the transmitting unit S_2 begins to operate. The transmitting unit S_2 transmits within a frequency band different from that of the transmitting unit S_1. Its frequency thus will vary in the manner shown by the curve *c*—*d* in Fig. 2, until after a further half revolution the transmitting unit S_2 is uncoupled and the transmitting unit S_1 is again coupled in.

If the movement takes place very slowly, there is a possibility that the motor M may not start immediately upon switching between the two transmitting units. This may be avoided if, as mentioned above, the operation of both of the transmitting units is made to overlap during a short interval.

The receiver units are provided with condensers C_{m1} and C_{m2}, respectively, which are cut in such a way that they produce the correct intermediate frequency when the controlled object is in the same position as the transmitter object. The receiver condenser C_{m1} corresponds to the condenser C_1 of the transmitter unit S_1, and the receiver condenser C_{m2} corresponds to the condenser C_2 of the transmitter unit S_2. Due to the above described operation of the receiver object the receiver will therefor always assume the same position as the transmitter object.

In order to vary the receiver frequency the usual methods for frequency calibration, known in the radio art may be used. A very much greater precision may, however, be obtained, if the condenser of the transmitter unit as well as of the receiver unit is designed to cover a greater control angle than 180°, e. g. as shown in the figure, 270°, the condensers being made to give a logarithmic frequency variation with the angle of rotation, at least within the range which is used.

One can then always choose an angle of 180° for the transmitting condensers and a different angle for the receiver condensers, at which the above mentioned frequency relation is present. In this way a simple condenser of the same shape is obtained for the transmitter as well as for the receiver while maintaining an accurate alignment between the angles of rotation of the transmitter and of the receiver.

It is easy to prove mathematically, that in this

case the inductance coils in parallel to the condensers should have inductance values which are in a proportion to each other as the squares of the mean frequencies of the frequency bands, respectively. The shunt capacities on the receiver and on the transmitter should be as nearly equal to each other as possible.

After this preliminary explanation of the operation of a simple system embodying the invention, the transmitter according to Fig. 3 may be described. This transmitter is arranged to provide a main movement and a movement which is subordinated under this main movement, the last mentioned movement being here supposed to be a vernier movement. The shaft of the transmitter object is referred to as 10. This shaft may for instance be connected to some indicator which may be read in a remote place. Such an indicator is schematically shown at 11. On the shaft 10 there is arranged a worm gearing 12, by which the shaft 10 is connected to another shaft 13 in a gear ratio of 100:1, the last named shaft determining the main movement. The shaft 10 carries a rotor 14 of a double condenser, having double stators 15 and 16. Thus one condenser is formed between the rotor 14 and the stator 15, whereas another condenser is formed between the rotor 14 and the stator 16. A cam wheel 17, carried by the shaft 10, causes a contact spring 18 to be in contact with the contact point 19 during substantially half of a revolution of the cam 17 and with the contact point 20 during substantially the oher half of its revolution.

The shaft 10 is grounded, so that the condenser 14—15 is permanently coupled in parallel to the coil 21 of an oscillator valve 22, and the condenser 14—16 is in a corresponding manner permanently coupled in parallel with the coil 23 of a second oscillator valve 24. The oscillation circuit, formed by the coil 21 and the condenser 14—15 may, however, be short-circuited by means of the contacts 18—19 and in a corresponding way the oscillation circuit of condenser 14—16 and coil 23 may be short-circuited by contacts 18—20. The anode circuits of the oscillator valves 22 and 24 are inductively coupled to the transmission line 25.

The shaft 13 carries a further condenser, including a rotor 26 and a stator 27. This condenser is coupled in parallel to the coil 28 of an oscillator valve 29, the anode circuit of which is also connected inductively to the transmission line 25.

For explanation of the operation of the transmitter, reference is made to Fig. 4. It is assumed that the shaft 10 turns a plurality of revolutions in clock-wise direction. Due to its rotation the capacity 14—15 will initially increase, so that the frequency of the oscillator 22 decreases successively. The oscillation circit of oscillator 24 is short-circuited by the contacts 18 and 20. At the same time also shaft 13 turns, but due to the gearing this takes place in counter-clockwise direction and also at a speed which is assumed to be only one hundredth of the speed of rotation of shaft 10. The capacity of condenser 26—27 will therefor successively decrease, and the created frequency will increase. When shaft 10 has turned half a revolution, the short-circuit of condenser 14—16 is opened, so that the oscillator 24 becomes active, and a moment later the oscillation circuit of oscillator 22 becomes short-circuited, this oscillator thereby becoming inactive. After a further half revolution condenser 22 becomes again active, and oscillator 24 is put out of action.

The oscillators 22 and 24 have similar condensers, because of the fact that the condensers have a common rotor. Also the coils 21 and 23 are similar. The frequencies therefore will vary in the manner shown in Fig. 4. The line 30, drawn in full, represents the frequency of oscillator 29, and the line 31 represents the frequency of oscillator 22 and the line 32 represents the frequency of oscillator 24. Parts of the lines 31 and 32, which are drawn in full, represent operating periods of the respective oscillators, whereas the broken parts of these lines represent the time while the oscillation circuits of the oscillators are short-circuited.

The receiver for the transmitter of Fig. 3 is shown in Fig. 5. The transmission line is also here designated as 25. It is inductively coupled through a transformer 33 to the receiver for the main signal and also through two transformers 34 and 35 to each of two cooperating receivers for receiving the vernier signal. The main signal receiver consists of an oscillator valve 36 connected in a standard manner to operate as a combined oscillator and modulator. The connections for this valve are here of no importance except as far as this valve converts the main signal frequency to a frequency corresponding to the difference between the main signal frequency and the oscillator frequency, such as the intermediate frequency in a superheterodyne receiver. The transmitter frequency may have a range of 150–200 kcs. and the receiver oscillator frequency a range of 250–300 kcs., producing an intermediate frequency 100 kcs. Of course the invention could also be used according to the infraheterodyne principle, although it has not been found as advantageous.

The oscillator circuit of the oscillator valve 36 contains the coil 37, coupled in parallel with a trimmer condenser 38 and the tuning condenser 39. Condenser 39, which is thus the main tuning condenser, is mounted on the same shaft as the control motor 41 for the receiver object 42, which is here as a matter of simplicity shown in the form of a simple dial.

The anode circuit of the oscillator valve contains a circuit tuned to the exact value of the intermediate frequency and containing the condenser 43 and the coil 44. Coil 44 is inductively coupled to a second coil 45, tuned by means of condenser 46. Further the coils 44 and 45 are connected to each other by means of a condenser 47, which is connected between the mid-point of one of the coils, for instance, coil 45, and the high potential end with reference to alternating current of the other coil, in this case the coil 44. This coupling arrangement is sharply tuned and is known per se. It operates in the following manner:

The voltage of a tuned primary circuit and in a tuned secondary circuit are normally displaced in phase by 90°. If the primary voltage is added, as by the condenser 47, to one half of the secondary voltage in positive direction and to the other half of the secondary voltage in negative direction, due to the symmetry between these two voltages the resulting vectors will be exactly equal. If the frequency differs from that to which the circuits are tuned, however, the symmetry is destroyed. Of course the two half voltage vectors of the secondary voltage are still equal, but one of them, due to the changed phase relation between primary voltage and secondary voltage, will

form an acute angle with the primary voltage vector, whereas the other one forms an obtuse angle. The former resultant will thereby be essentially greater than the latter one, and if both of the voltages are rectified different direct current voltages will be obtained.

The rectifiers, in which the rectification is made, are in the figure shown as valves 48 and 49, which work on the load resistors 50 and 51, respectively. The voltages across the respective load resistors are fed each to one of two direct current amplifier valves 52 and 53, the anode circuits of which are connected each to one of the field windings 54 and 55 of the motor 41.

The coupling arrangement for vernier reception is arranged in substantially the same manner as the main receiving system. The only difference is that two cooperating receivers are provided, one of which responds to the frequency 31 and the other to the frequency 32 in Fig. 4. In order to simplify the description the same reference numerals have been used in the vernier receivers as in the main receiver, said reference numerals having been increased by one hundred for one of the vernier receivers and by two hundred for the other.

The two receiver units are provided with condensers with a common rotor 58, mounted on the common control shaft 56, which is driven by motor 57. The shaft 56 actuates the receiver object 59, which is shown as a vernier dial. The anode circuits of the direct current amplifier valves 152 and 252 are connected together and connected to supply field current to the field winding 60 of motor 57, whereas the direct current amplifier valves 153 and 253 are connected together to supply field current to the field winding 61.

The operation of the arrangement is the following:

When shaft 10 in Fig. 3 turns, it causes the transmission of two different frequencies, indicated by the curves 31 and 32 of Fig. 4, which vary as a function of the angular position of the shaft 10. Another frequency is transmitted by oscillator 29 in the form indicated by the curve 30 in Fig. 4, which is a function of the angular position of the shaft 13. For each half revolution of the shaft 10 a full frequency range, corresponding to the capacity variation during 180° of the condenser 14—15 and 14—16, respectively, is run through by the transmitter units 22 and 24, as shown in Fig. 4 by curves 31 and 32 respectively.

On the receiver side the frequency 30 is received by means of the transformer 33 of the main receiver, in which it is modulated with the frequency created by oscillator valve 36, so that an intermediate frequency is formed. If it now should happen that this intermediate frequency agrees with the frequency to which the discriminator 43—46 is tuned, the reception of the frequency 30 does not result per se in the operation of the motor 41 of the receiver. If, however, the frequency differs from the above, a stronger magnetizing current is obtained through one of the windings 54 and 55 of the motor 41, which causes the motor to operate and the shaft 40 is tuned, until condenser 39 has reached such a position that the correct frequency is restored in the intermediate frequency channel of the main receiver. The dial 42 then will take the position corresponding to that of the main transmitter, but which according to the suppositions may not have sufficient precision.

At the same time as the frequency 30, Fig. 4, is transmitted, transmission of a further frequency 31 or 32 from the vernier transmitter takes place. This is received by means of the receivers which contain oscillator valves 136 and 236, respectively. As a matter of fact, the frequency is received by both of these receivers, but only one of them is in the position to operate. Assume, for instance, that the main receiver has been roughly positioned so that the oscillator 136 operates, then due to the characteristic of the discriminators of this type a substantial voltage difference may be obtained between the direct current voltages created by rectifiers 148 and 149 if the shaft 56 is not correctly positioned. This direct current voltage difference influences the field windings of motor 57, so that an automatic correction is obtained.

Meantime, however, the oscillator 236 produces an intermediate frequency with the incoming frequency, but this differs widely from the intermediate frequency to which the discriminator is tuned. Since discriminators of this kind produce very small or no current deviation, when the frequency is widely displaced from the discriminator frequency, the result is that about equally strong field currents are delivered by the amplifier valves 252 and 253 to windings 60 and 61, said currents also being substantially weaker than the currents delivered by valves 152 and 153. The fact that the oscillator 236 is allowed to operate at the same time as oscillator 136 therefore does not cause any appreciable disadvantage.

If necessary, a contact arrangement (not shown) may be provided on shaft 56, by means of which the field windings 60 and 61 are connected in turn to the valves 152 and 153 and to the valves 252 and 253.

When the system has been out of operation, one can not with certainty assume that the transmitter and receiver are in agreement. It thus may happen that the receiver or the transmitter has meantime changed its position, so that a difference in position of half a revolution of shaft 10 or a multiple of such a half revolution has occurred. In order to prevent this, the motor 41 may be made strong enough in relation to the motor 57 to always secure correct rough adjustment within a range of tolerance which is less than plus or minus a quarter of a revolution of the shaft 10, or the motor 57 may be cut off until the motor 41 has completed control within the said tolerance. This may be done by connecting the field windings 54 and 55 of motor 41 in series through the windings 62 and 63 of a differential relay 65 having a contact 64. At certain differences between the currents through said windings 62 and 63 the contact 64 of the relay opens the armature circuit of motor 57, which is not closed until the difference between the two currents have decreased to a sufficiently low value.

Of course it is possible to utilize additional stages of vernier adjustment to obtain a still more exact adjustment. In this manner it is possible to obtain a precision in the remote control which is only limited by the mechanical precision of the gearing. If the invention is used to control with high precision the position or direction of some object, for instance, a piece of ordnance, the control mechanism of the piece may be connected with the shaft 56 as indicated by the dial 59.

What we claim is:

1. In a remote control apparatus, a transmitter including a pair of units each having means

for producing and transmitting signals having frequencies variable over a predetermined range and including a control member to control as a function of its position the frequency of said signal, and a receiver, including a controlled object, and a pair of units tuned for receiving the signals transmitted from said first units, said last units each having means responsive to variations in the frequency of the received signal from the frequency to which said last units are tuned for effecting a control of said object corresponding to the movement of said control member, said control member being connected to cause said first units to alternately transmit signals sweeping over their respective ranges, whereby said controlled object is controlled alternately by the receiver units of said pair.

2. An apparatus as defined in claim 1 including a tuning circuit for each of said units of said pair, and a variable condenser having two stators and a common rotor, one of said stators being included in the tuning circuit of one of said pair of units and the other stator being included in the tuning circuit of the other of said pair of units.

3. A remote control apparatus as defined in claim 1 in which the signals transmitted by the units of said pair are variable over different ranges.

4. In a remote control apparatus, a transmitter including a pair of units having means for producing and transmitting signals having frequencies variable over a predetermined range and including a control member to control as a function of its position the frequency of said signals, and a receiver, including a controlled object, and a pair of units tuned for receiving the signals transmitted from said first units, said last units each having means responsive to variations in the frequency of the received signals from the frequency to which said last units are tuned for effecting a control of said object corresponding to the movement of said control member, said control member being connected to cause the frequency of one of said signals to vary at a rate substantially greater than that of the other of said signals and to cause said first signal to successively sweep over its range while said second signal varies progressively and continuously in the same direction during a predetermined range in movement of said control member whereby said first signal may be used for effecting fine adjustment of said controlled object and said second signal may be used for effecting coarse adjustment thereof.

5. In a remote control apparatus according to claim 4 in which the signals are respectively intended for fine control and coarse control, rotatable tuning means at the transmitter and receiver for each of said signals and reducing gears interconnecting the rotatable tuning means for the fine and coarse signals at the transmitter and receiver.

6. In a remote control apparatus according to claim 4 in which the signals are respectively intended for fine control and coarse control, rotatable tuning means in the respective channels at the receiver, and motors actuating said tuning means in response to frequency variations in the received signals, the motor actuating the tuning means for the coarse control being sufficiently powerful to effect control regardless of the energization of the fine control motor.

7. In a remote control system according to claim 4 in which the signals are respectively intended for fine and coarse control, control means responsive to each of said signals and means rendering the fine control means ineffective until the approximately correct coarse control is effected by the coarse control means.

8. In a remote control system according to claim 4, tuning means for the control channels including variable condensers having logarithmic capacity characteristics.

9. In a remote control system according to claim 4, tuning means for the control channels including variable condensers having logarithmic capacity characteristics, the condensers of the respective channels being angularly displaced relative to each other.

10. In a remote control apparatus, a transmitter including a unit having means for producing and transmitting a signal having a frequency variable over a given range and a pair of units having means for producing and transmitting signals having frequencies variable over different ranges and including a control member to control, as a function of its position, the frequencies of said signals within the respective ranges, and a receiver, including a controlled object, a unit tuned for receiving the first-mentioned signal and having means responsive to variations in the frequency of said first signal from the frequency which said unit is tuned to receive for effecting control of said controlled object, and a pair of units each tuned for receiving said second mentioned signals, and having means responsive to variations in the frequency of said last signals from the frequency which said units are tuned to receive for modifying the control of said object.

11. An apparatus as defined in claim 10 in which said control member is connected to vary the frequency of said signals at different rates, the slower varying frequency constituting a coarse adjustment of said object and the more rapidly varying frequency constituting a fine adjustment of said object.

12. In an apparatus as defined in claim 10, means alternately rendering the units of said pair operative, said means being connected to said control member to cause the signals from said last units to alternately sweep over their respective ranges in response to continued movement of said control member.

13. In an apparatus as defined in claim 10, means alternately rendering the units of said pair operative, said means being connected to said control member to cause the signals from said last units to alternately sweep over their respective ranges in response to continued movement of said control member, said last means causing the periods of energization of the respective units of the pair of transmitting units to overlap whereby continuous control is effected thereby.

14. An apparatus as defined in claim 10 in which said second mentioned signals are variable over the same range as each other, but over a different range from that of the first mentioned signal.

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