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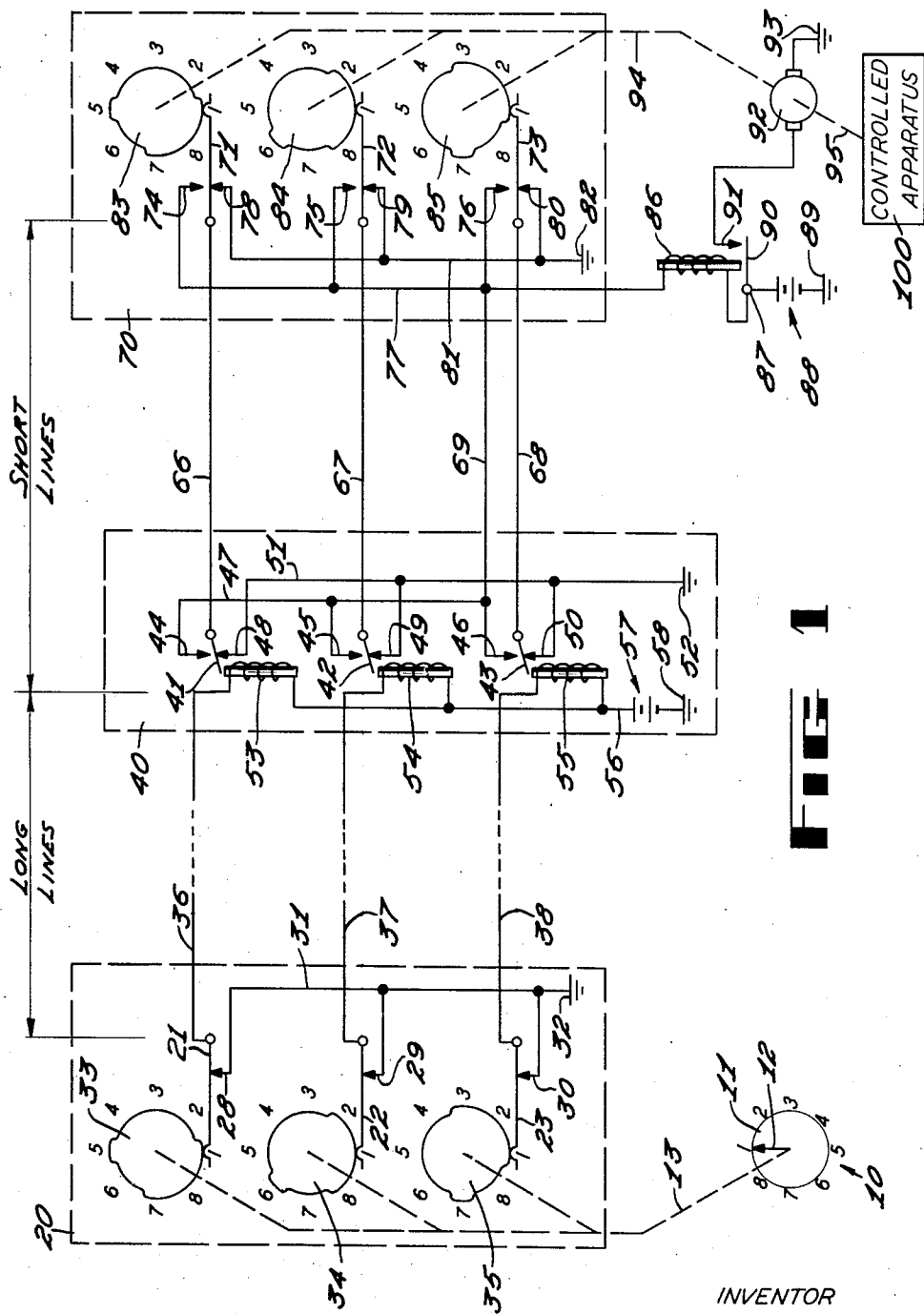
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2,808,557

REMOTE CONTROL SERVOSYSTEM

Filed June 23, 1954

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

CODER POSITION	CONDITION OF ELEMENTS											
	CODER			REPEATER			DECODER					
	21	22	23	41	42	43	71	72	73	74		
1	-	-	-	-	-	-	-	-	-	+		
2	+	-	-	+	-	-	+	-	-	+		
3	+	+	-	+	+	-	+	+	-	+		
4	+	+	+	+	+	+	+	+	+	+		
5	-	+	+	-	+	+	-	+	+	+		
6	+	-	+	+	-	+	+	-	+	+		
7	-	+	-	-	+	-	-	+	-	+		
8	-	-	+	-	-	+	-	-	+	+		
SYMBOLS: - GROUNDED + UNGROUNDED			SYMBOLS: - GROUNDED + POSITIVE									

FIG 2

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1

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REMOTE CONTROL SERVOSYSTEM

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5 Claims. (Cl. 318-467)

This invention relates to remote signaling systems, and particularly to that type of signaling system in which the information to be transmitted is translated at a control station to binary code for transmission over interconnecting lines to a controlled station. At the controlled station the information is decoded and utilized to control associated apparatus. This type of system is particularly useful in shaft positioning apparatus. It is extensively used for control of radio apparatus such as for remotely positioning a tuning element, a selector switch or the like.

A binary code signaling system is especially advantageous in that a small number of transmission lines is required to transmit a large number of bits of information. Because of this attribute, the system has become known as a "Wire Saving System." This type of system operates upon the principle that a group of n elements, each element having two different conditions, taken n at a time, can be arranged in 2^n different ways, constituting 2^n permutations. With each permutation representing a different bit of information, the system can accommodate 2^n bits of information.

In utilizing this principle to transmit information to a remote station, the elements used are electrical switches and the stations are connected by transmission lines. In a shaft positioning control system, for example, a selector unit is used to select one of a plurality of discrete shaft positions and is drivingly connected to a coder at the control station. Each discrete position represents one bit of information. The coder operates to arrange the group of two-condition switches in successively different permutations. Each switch is connected by a transmission line to the controlled station which includes a decoder. The decoder is provided with a similar group of two-condition switches, each of which is connected to a different one of the transmission lines. The decoder is motor driven to arrange the switches in the successively different permutations and the motor remains energized so long as the permutation of the decoder is out of correspondence with the permutation of the coder. Thus, the motor shaft and any controlled apparatus connected thereto are driven to a position corresponding to that selected by the selector unit. This system is fully described and claimed in U. S. Patent 2,476,673, issued to R. W. May et al., on July 19, 1949, and assigned to the assignee of the present invention.

The system of the May et al. patent just described can theoretically transmit 2^n bits of information over n wires. In practice, however, this is not feasible because one of the 2^n permuted connections of the coder and decoder switches is that in which all switches are connected to the grounded terminal of the voltage source. This leaves the system in a "dead position" and the system is incapable of recovering or moving off this position. Therefore, in practice, such a system is used to transmit, as a maximum number, $2^n - 1$ bits of information. The dead condition is thus avoided.

The present invention provides a system in which 2^n bits of information can be transmitted over n lines repeti-

2

tively without the occurrence of a "dead position." Stated otherwise, the same amount of information can be transmitted over one less line than has been required in systems known heretofore. Although the inventive system involves the use of a repeater station the advantage to be gained by the elimination of one transmission line may far outweigh the disadvantage of this requirement. This is particularly true where the control and controlled stations are separated by great distances. In such installations a repeater station is commonly used because the reactance and the time constant of the long transmission lines are appreciable. The repeater station is then required for improving the speed of response and accuracy of the system.

This invention also provides a system for transmitting 2^n bits of information with a group of n switches at the coder and decoder when interconnected by $n+1$ transmission lines. In this aspect, the invention does not require an interposed repeater station and will find its greatest usefulness where the distance between the coder and decoder is not great.

Accordingly, it is an object of this invention to overcome disadvantages of the known systems of binary code signaling by providing a system in which all permutations of the elements are usable and which is capable of recovering from any one of the conditions.

More particularly, it is an object of this invention to provide a binary code signaling system which is capable of repetitively transmitting 2^n bits of information over n wires.

It is a further object to provide a position control system in which a maximum number of positions may be remotely controlled over a minimum number of transmission lines.

A further object is to provide a signaling system in which two groups of n switch units are required to transmit 2^n bits of information.

These and other objects and the manner in which they are accomplished will become more apparent from the description which follows taken with the accompanying drawings, in which:

Figure 1 is a schematic diagram of the inventive system.

Figure 2 is a tabular presentation of the conditions of the elements in each permutation for the system of Figure 1.

The inventive system comprises a repeater station interposed between the control and controlled stations. The control element of each switch at the repeater station is connected by a separate conductor to the control element of the corresponding switch at the controlled station. The first conductive elements of each switch at both stations are connected to one terminal of a power source through a common circuit such as a ground connection. The second conductive elements of each switch are connected to the other terminal of the voltage source through an additional conductor between the stations. By this arrangement the system is enabled to recover from the condition in which the control elements of all switches are connected to the same terminal of the voltage source. This result follows because the change of condition of any switch at the repeater by operation of the coder will cause the conductor connected to that switch to be connected across opposite terminals of the voltage source. This will energize that conductor and hence the driving means for the decoder. Thus the system permits all permutations to be used.

In the illustrative embodiment, the system is applied to a shaft positioning control system. It is shown as a three-wire system between the control station and repeater station, although any other suitable number of

wires may be used, depending upon the maximum number of bits of information it is desired to transmit. Where n is equal to 3, as illustrated, the maximum number of information bits is 2^3 and 8.

In Figure 1, the system comprises a selector unit 10 and a coder unit 20 at the control station. A repeater station 40 is connected with the control station by a plurality of transmission lines 36, 37 and 38. These lines are shown as long lines, for example, a number of miles; however, the system operates in the same manner over relatively short lines. The repeater station 40 is connected with the controlled station through conductors 66, 67, 68 and 69. The control station includes a decoder unit 70 and a controlled apparatus 100.

The control unit 10 comprises a selector dial 11 provided with spaced index marks around its periphery. The index marks are numbered to identify the different shaft positions which may be selected. A rotatable selector arm 12 is movable over the face of the dial to select a desired shaft position. The shaft 13 of the selector 10, indicated schematically, is connected to coder unit 20.

The coder unit 20 comprises a plurality of 2-condition switches. In the illustrative embodiment, the 2-condition switches are of the single pole double throw type. Any suitable type of switch element may be used such as the wafer type switches which are fully described in the above-mentioned patent to May et al. The single pole double throw type of switch is employed in the exemplary embodiment for the reason that the schematic illustration of this type lends itself well to explanation of the operation.

The plural switches of the coder 20 comprise, respectively, a control element or movable contact 21, 22, and 23. In a first condition of each switch the movable contact 21, 22, and 23 is disconnected from the fixed element or contact 28, 29, and 30, respectively. The movable contacts 21, 22, and 23 are engageable respectively in a second condition, with fixed contacts 28, 29, and 30. Each of these contacts is connected through a common conductor 31 to ground connection 32. Each of the contacts 21, 22, and 23 is movable independently of the others, preferably in a predetermined pattern or sequence between the first condition and second condition.

In order to operate the switch contacts between the first and second positions, each element 21, 22 and 23 is provided with an operating cam 33, 34 and 35, respectively. These cams are preferably of insulating material and are nonrotatably secured to the shaft 13 which is driven from the selector 10. Each of the cams 33, 34 and 35 has its circumference divided into a number of spaces corresponding to the positions of the selector 10. Each space is characterized by a projection from the peripheral edge of the cam body or the lack of such projection. The pattern of the projections determines the desired sequence of operation of the associated switch element. Note that the pattern is the same on all cams, but that the cams are secured to the shaft at different angular positions. The movable contacts 21, 22 and 23 are resiliently urged into engagement with the peripheral edge of the respective cam and are moved according to whether or not the rotative position of the cam presents a projection. In the position of the selector illustrated, the rotative position of each cam is such that the movable contacts engage a rise in the cam surface and consequently each switch blade is positioned against the fixed contacts 28, 29 and 30, respectively. In this position of the selector switch, each of the switch blades is connected to ground.

The switch contacts 21, 22 and 23 of the coder are connected at one terminal with a corresponding transmission line 36, 37 and 38, respectively, which extend to the repeater station 40. At the repeater station, each of the lines 36, 37 and 38 is connected through the energizing winding of the electromagnetic relays 53, 54 and 55, res-

spectively. Each of the lines is then connected through a common conductor 56 to a voltage source 57 which has its other terminal connected to ground 58. Associated with each of the relays 53, 54 and 55 and actuated thereby is a movable switch contact 41, 42 and 43, respectively. Positioned adjacent each of the movable switch contacts 41, 42 and 43 is a fixed contact 44, 45 and 46 against which the movable contacts are normally closed. These fixed contacts are connected to a common conductor 47. Also positioned adjacent each of the movable contacts 41, 42 and 43, respectively, is a fixed contact 48, 49 and 50. These fixed contacts are connected to a common conductor 51 which is connected to ground 52.

Each movable contact 41, 42 and 43 is connected at one terminal to a corresponding conductor 66, 67 and 68, respectively, which extends from the repeater station 40 to the decoder station 70. An additional conductor 69 is connected to the common conductor 47 and extends also between the repeater station 40 and decoder station 70.

At the controlled station 70, there is provided a decoder including a plurality of switches, each having a control element or movable contact 71, 72 and 73 which is connected at one terminal to corresponding conductors 66, 67 and 68, respectively. Each of the movable contacts 71, 72 and 73 is provided with an adjacent fixed contact 74, 75 and 76, respectively. These contacts are connected through a common conductor 77 to the additional conductor 69. Also, adjacent each of the movable contacts 71, 72 and 73 is positioned a fixed contact 78, 79 and 80, respectively. These contacts are connected through a common conductor 81 to ground connection 82.

Actuating means for each of the movable contacts 71, 72 and 73 are provided in the form of cams 83, 84 and 85 against which the contact arms are resiliently urged. All of the cams have the same peripheral edge configuration, but are fixedly mounted to a common shaft 94 in different angular positions. The cams 83, 84 and 85 are also of the same configuration as the cams 33, 34 and 35, previously described. The common conductor 77 and the additional conductor 69 are connected through the energizing winding of the electromagnetic relay 86 to terminal 87 and thence to one terminal of voltage source 88. The other terminal of the voltage source 88 is connected to ground 89.

Also connected to the terminal 87 is a movable contact 90 actuated by relay 86 to engage or disengage fixed contact 91. The fixed contact 91 is connected to one terminal of direct current motor 92. The other terminal of the motor is connected to ground 93. The motor-driven shaft 94 is connected to each of the cams 83, 84 and 85 and the motor-driven shaft 95 is connected with the controlled apparatus, such as a tuning device 100.

The operation of the inventive system is as follows: An operator at the control station rotates the selector arm 12 to the position which it is desired to reproduce by the motor shaft and associated controlled apparatus at the controlled station. For example, in Figure 1 the selector arm is placed in position 1 and the coder cams 33, 34, and 35 are thereby rotated to position 1. In this position each of the cams presents a projection to the movable contact arms 21, 22 and 23, and each of the movable contacts is connected to the fixed contacts 28, 29 and 30 respectively. These fixed contacts are connected through common conductor 31 to ground 32. The condition of the coder elements for selector position 1 is shown in tabular form in Figure 2 where the symbol indicates that the movable contact is connected to ground. With the switch contacts in this condition there is a circuit completed from the upper terminal of voltage source 57 through common conductor 56, through the energizing winding of relay 53, transmission line 36, movable contact 21, fixed contact 28, conductor 31, to ground 32, and through the common ground circuit to the other terminal of voltage source 57. A similar circuit is com-

5

pleted from the positive terminal of voltage source 57, relay 54, transmission line 37, switch contacts 22 and 29, and through the common ground circuit back to the voltage source 57. Also, a circuit is completed in the same manner from voltage source 57 through relay 55, transmission line 38, switch contacts 23 and 30, and through the common ground circuit to the other terminal of source 57. Thus each of the relays 53, 54 and 55 is energized and the movable contacts 41, 42 and 43 respectively are actuated to engage the fixed contacts 43, 49 and 50. In this condition each of the movable contacts of the relay-operated switches is connected through the common conductor 51 to ground 52. This condition of the relay-operated switches is shown in the table of Figure 2 in which the symbol —, for the repeater station, indicates that the movable contact is connected to ground.

If, at the time the selector 10 is moved to the position 1, the decoder switches at the controlled station 70 are in a condition such that any one of the movable contacts 71, 72 and 73 is connected to the fixed contact 74, 75 or 76, an energizing circuit will be completed. Assuming that contact 73 engaged contact 76, such an energizing circuit would extend from the positive terminal of the voltage source 88 through the winding of relay 86, common conductor 77, fixed contact 76, movable contact 73, transmission line 68, movable contact 43, fixed contact 50, conductor 51, and through the common ground return circuit 52 to the other terminal of voltage source 88. The relay winding 86 will be energized and the relay-operated contact 90 will engage fixed contact 91 to close the motor energizing circuits. The motor energizing circuit extends from the upper terminal of the voltage source 88 through the relay contacts 90 and 91 to one terminal of the direct current motor 92 and through the other terminal of the motor to the ground return circuit 93 to the other terminal of the voltage source 88. Thus the motor is energized and will rotate until the motor shafts 94 and 95, together with the shaft-driven controlled apparatus 100, assume an angular position in which the decoder cams 83, 84 and 85 operate the movable contacts 71, 72 and 73 to a condition in which these contacts are connected to ground. This condition is illustrated in Figure 1 in which each of the coder cams presents a projection to each of the movable contacts 71, 72 and 73, and causes each contact to engage the fixed contacts 78, 79 and 80 respectively. This condition with the energizing circuit interrupted, is represented in tabular form in Figure 2. When this condition is reached the motor 92 comes to a stop and the position of the controlled apparatus 100 corresponds to that of the selector unit 10 at the control station.

Assuming now that it is desired to reposition the controlled apparatus 100 to the position 2, the selector arm 12 is set accordingly. This operation rotates the coder cams 33, 34 and 35 in unison through the common shaft 13. The condition of the coder switches is readily determined from the table of Figure 2, which shows that movable contact 21 is ungrounded, while movable contacts 22 and 23 are connected to ground. This condition results in the de-energization of relay 53, since the circuit extending from the positive terminal of source 57 through relay 53 is interrupted by contact 21. Accordingly, the relay-operated switches at the repeater station 40 are placed in the condition shown by the table of Figure 2. Movable contacts 42 and 43 are connected to ground and movable contact 41 is connected, by way of fixed contact 44, and conductors 47 and 69, to the positive terminal of the voltage source 88. This circuit is completed through the transmission line 66 to the movable contact 71 and fixed contact 78, common conductor 81 to ground 82 and through ground circuit to the other terminal of the voltage source 88. At the same time the movable contacts 42 and 43 are in engagement with the fixed contacts 49 and 50, which are connected to ground.

6

Since movable contacts 72 and 73 are also connected to ground the circuits including conductors 67 and 68 are de-energized. However, the circuit just described through movable contact 41, transmission line 66, and movable contact 71 causes the relay 86 to be energized which actuates contact 90 into engagement with fixed contact 91, completing the energizing circuit from the voltage source 88 through the motor 92. Thus the motor is caused to rotate and will continue to do so until the motor shaft assumes a position in which the movable contact 71 is disconnected from ground and connected to the positive terminal of the voltage source 88 through the fixed contact 74. In this position the relay 86 is de-energized since no completed circuit exists from the positive terminal of the source 88 through the conductors 66, 67 or 68 and back through ground to the other terminal of the voltage source.

It will now be apparent that in moving from position 1 to any other of the selectable positions the relay 86, and hence, motor 92 were energized by virtue of the fixed contacts 44, 45 and 46 being connected through the additional conductor 69 to the positive terminal of the voltage source 88. In position 1 of the decoder cams all of the movable contacts 71, 72 and 73 are connected to ground 82 and it is only by connection of one of the movable contacts 41, 42 or 43 to the positive terminal of the source that the relay may be energized. It is by the addition of conductor 69 extending from the voltage source 88 to the repeater contacts 44, 45 and 46 that the system is enabled to recover from or move off the position in which all of the decoder contacts 71, 72 and 73 are connected to ground.

As previously described, each position of the selector arm 12 establishes a corresponding position of the coder cams 33, 34 and 35. For each such position the coder switches are set in a different permutation of connections. Each such permutation is reproduced at the repeater station by the relay-operated contacts. This causes the driving motor to be energized and to rotate the decoder cams 83, 84 and 85 until a permutation of the decoder switches is established which corresponds to the permutation of the coder switches. At this point the motor is de-energized and the controlled apparatus is positioned according to the setting of selector arm 12.

It will be appreciated that each position is considered as a different bit of information and that the maximum number of bits of information which may be transmitted repetitively by this system depends upon the number of transmission lines interconnecting the control station and the repeater station. This relation is given by the quantity 2^n where n is the number of such transmission lines.

Another aspect of the invention is found in that portion of the system which interconnects the repeater station 40 and the decoder station 70. It will be appreciated that the repeater station 40 merely serves to reproduce the permutation set up by the coder station 20. It will be apparent, then, that the repeater station may itself be considered as a coder station for the control of the decoder station 70. Since the switches at station 40 may be set in 2^n different permutations, it is apparent that 2^n different bits of information may be transmitted and decoded by the decoder station 70. These 2^n different bits of information may be repetitively transmitted, as explained hereinbefore. With a group of n switches at station 40 and at station 70, the required number of transmission lines in addition to the common return path is n plus 1. In summary, then, this aspect of the invention is characterized by a system which can repetitively transmit 2^n bits of information with a group of n switches at each station interconnected by n plus 1 transmission lines.

The invention has been described with respect to a particular embodiment which is to be taken as illustrative only. The type of switches employed in the illustrative system may be replaced by other suitable types

7

as mentioned previously. Certain features which may be incorporated into the system, such as a relay-operated stop mechanism for the decoder, have not been described or illustrated since such modifications and additions are well understood and form no part of the present invention. Numerous modifications will now occur to those skilled in the art. The illustrative embodiment is not to be construed as a limitation upon the scope of the invention. For a definition of the invention reference is made to the appended claims.

I claim:

1. A binary code transmission system comprising a plurality of n pairs of switches, each switch including a movable contact element connectable to a first or second fixed element, conductors connecting together the movable contact elements of each pair of switches, said first and said second fixed elements respectively being connected to opposite terminals of a voltage source, n relay windings for actuating the first movable contact element of each of said n pairs of switches, a remote switching means for selectively energizing said n relay windings with n wires to arrange the movable contact elements of said first switches in 2^n different permuted connections, and decoder motor means responsive to current flow in any one of said conductors for arranging the movable contact elements of the second switches of said n pairs of switches in a position corresponding to the selected positions of the movable contact elements of the first switches of said n pairs of switches, in which position said decoder motor means is de-energized.

2. A binary code transmission system comprising a control station, a repeater station and a controlled station, a plurality of switches at each of said repeater and controlled stations, each switch including a movable element connectable to cooperating first or second fixed elements, a conductor connecting the movable element of each switch at said repeater station to the movable element of a corresponding switch at said controlled station, said first fixed elements and said second fixed elements respectively of the switches at said repeater and controlled stations being connected to opposite terminals of a voltage source, relay winding means for actuating each of said switches at said repeater station, a plurality of switches at said control station, each having a movable element contacting a fixed element in one state and not contacting in another state, a transmission line connecting the movable element of each of said control station switches into a series circuit through a corresponding one of said relay winding means to one terminal of a voltage source, said fixed elements of the switches at said control station being connected to the other terminal of said last named voltage source, coder means including a plurality of similarly shaped cams for arranging said control station switches in permuted states, and decoder means including a plurality of similarly shaped cams responsive to current flow in any one of said conductors for connecting said controlled station movable elements to cooperating first or second fixed elements in a manner corresponding to the permuted states of said control station switches.

3. A shaft position control system comprising a plurality of pairs of switches, each switch including a movable element connectable to cooperating first or second fixed elements, conductors connecting the control elements of each pair of switches together, said first and second fixed elements respectively being connected to opposite terminals of a voltage source, a relay winding for operating the first switch of each of said pairs of switches, a remote switch means including a plurality of identically shaped actuating cams, said remote switch means being individually connected to each of said relays for selectively energizing each of said relays so as to arrange said first switches in 2^n different permuted connections, operating means including a like plurality of said cams for the second switches of said pairs of switches,

8

a motor having a shaft drivingly connected to said operating means, and means responsive to current flow in any one of said conductors for energizing said motor whereby said shaft is rotated until the connections of said second switch movable elements to cooperating first or second fixed elements correspond to the permuted connections of said first switches.

4. A binary code signaling system comprising a coder including a group of n two-position coder switches, switch operating means including a plurality of cams having identical configuration for arranging said coder switches sequentially in 2^n permuted connections, a group of n transmission lines each connected to a different one of said switches, a first return circuit including a first voltage source, each switch being connected in one position to said return circuit, each permuted connection of said coder switches energizing said transmission lines in different permutations, a repeater including a group of n relay-operated, two position repeater switches, the relay of each being connected to a different one of said transmission lines whereby said repeater switches are arranged in 2^n different permuted connections, a group of n conductors each connected to a different one of said repeater switches, a second return circuit, a second voltage source, a decoder including a group of n two-position decoder switches, each decoder switch being connected to a different one of said conductors, decoder switch operating means including a like plurality of said cams for arranging said decoder switches sequentially in 2^n permuted connections, each repeater switch and decoder switch in one position being connected through said second return circuit to one terminal of said second source, and in the other position being connected to the other terminal of said source, said operating means being energized in response to current flow through said second source whereby said decoder switches are arranged in positions corresponding to the positions of said decoder switches.

5. A binary code transmission system including a control station, a repeater station and a controlled station, a group of n transmission lines and a first return circuit between said control and said repeater stations, a first voltage source in said first return circuit, a coder at said control station including a group of n coder switches each having one terminal connected to a different one of said lines, each coder switch changeable between first and second connections by one of a plurality of individual cams each having identical configuration whereby said group of n coder switches may be arranged in 2^n permutations of coder switch connections by operation of said coder, said first connection comprising a conductive path between each of said lines and said return circuit, said repeater station including a group of n relay-operated switches, circuit means including the energizing circuits of each of said relays connected from each of said lines at said repeater station to said return circuit, a group of n conductors and a second return circuit between said repeater station and said controlled station, each of said relay-operated switches having one terminal connected to a different one of said conductors, each of said relay-operated switches changeable by relay operation between first and second connections whereby any selected one of said 2^n permutations is repeated upon operation of said coder, a decoder at said controlled station including a group of n decoder switches each having one terminal connected to a different one of said conductors, each decoder switch changeable by one of a plurality of said cams between a first and second connection whereby any one of said permutations may be set up by said decoder, driving means connected to said decoder for setting up sequentially each of said permutations, a control relay for energizing said driving means, said control relay being serially connected with a second voltage source, said first connections of each of said relay-operated switches and said decoder switches

being connected through said second return circuit to one terminal of said source, and an additional conductor connecting together the second connections of each of said relay-operated switches and said decoder switches, said additional conductor being connected to the other terminal of said voltage source whereby said control relay and said driving means are energized when the permutation existing in said decoder does not correspond with the permutation of said coder.

10

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