Aug. 21, 1928.

1,681,489

G. A. LOCKE ET AL

SIGNALING SYSTEM

Filed July 21, 1926 4 Sheets-Sheet 1

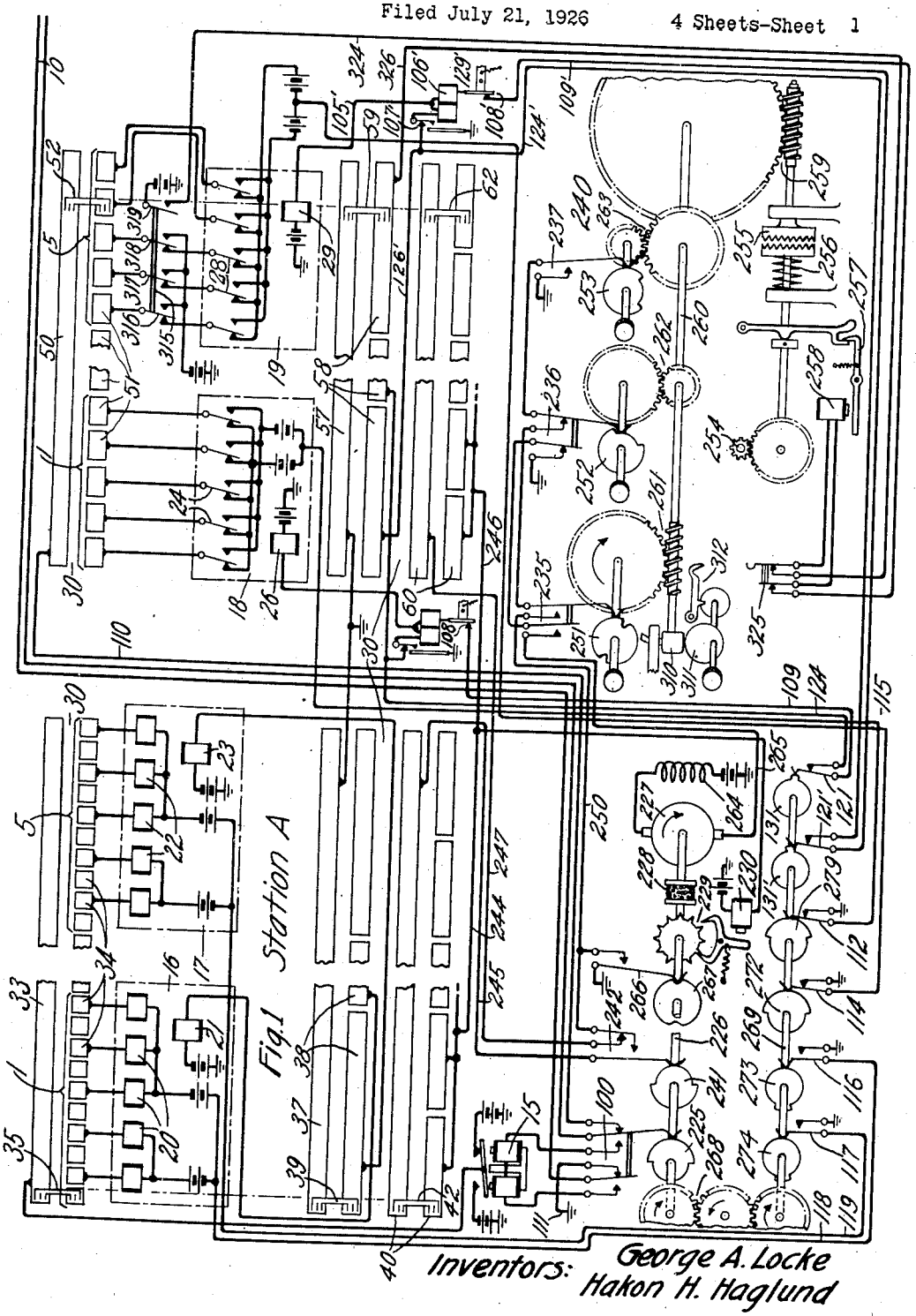


Fig. 1 Station A

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4 Sheets-Sheet 2

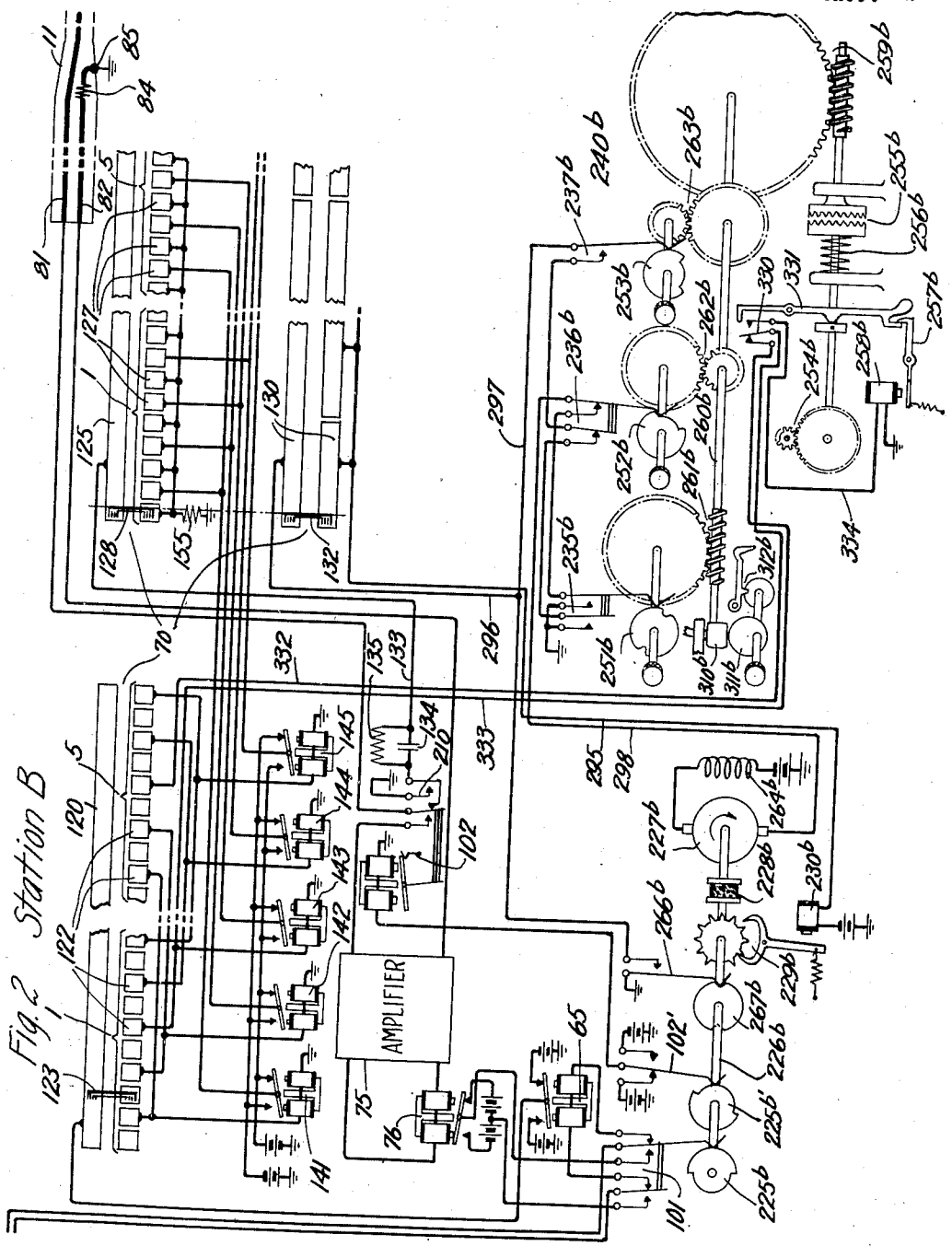


Fig. 2

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Aug. 21, 1928.

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4 Sheets-Sheet 3

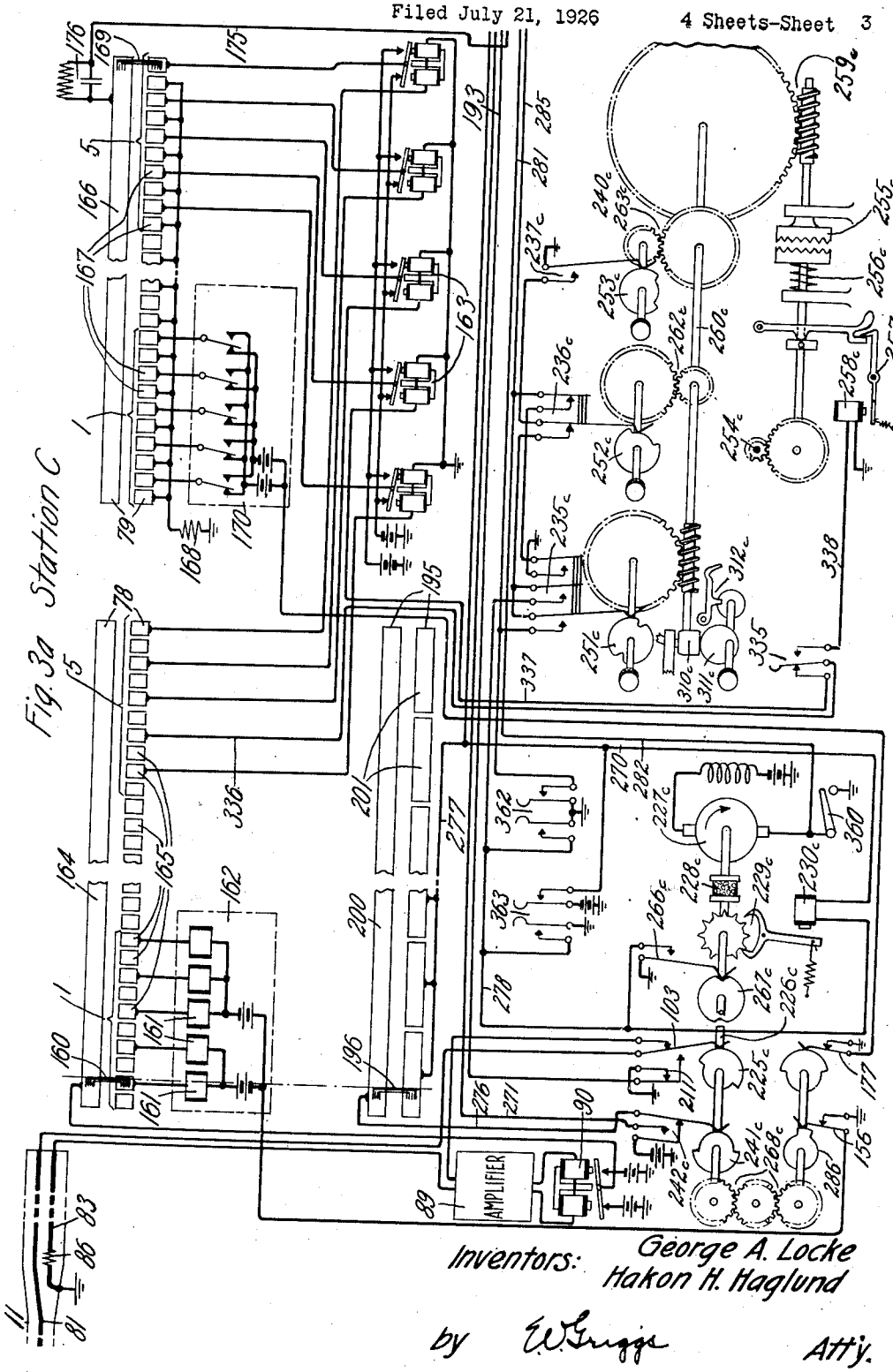


Fig. 3a Station C

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Aug. 21, 1928.

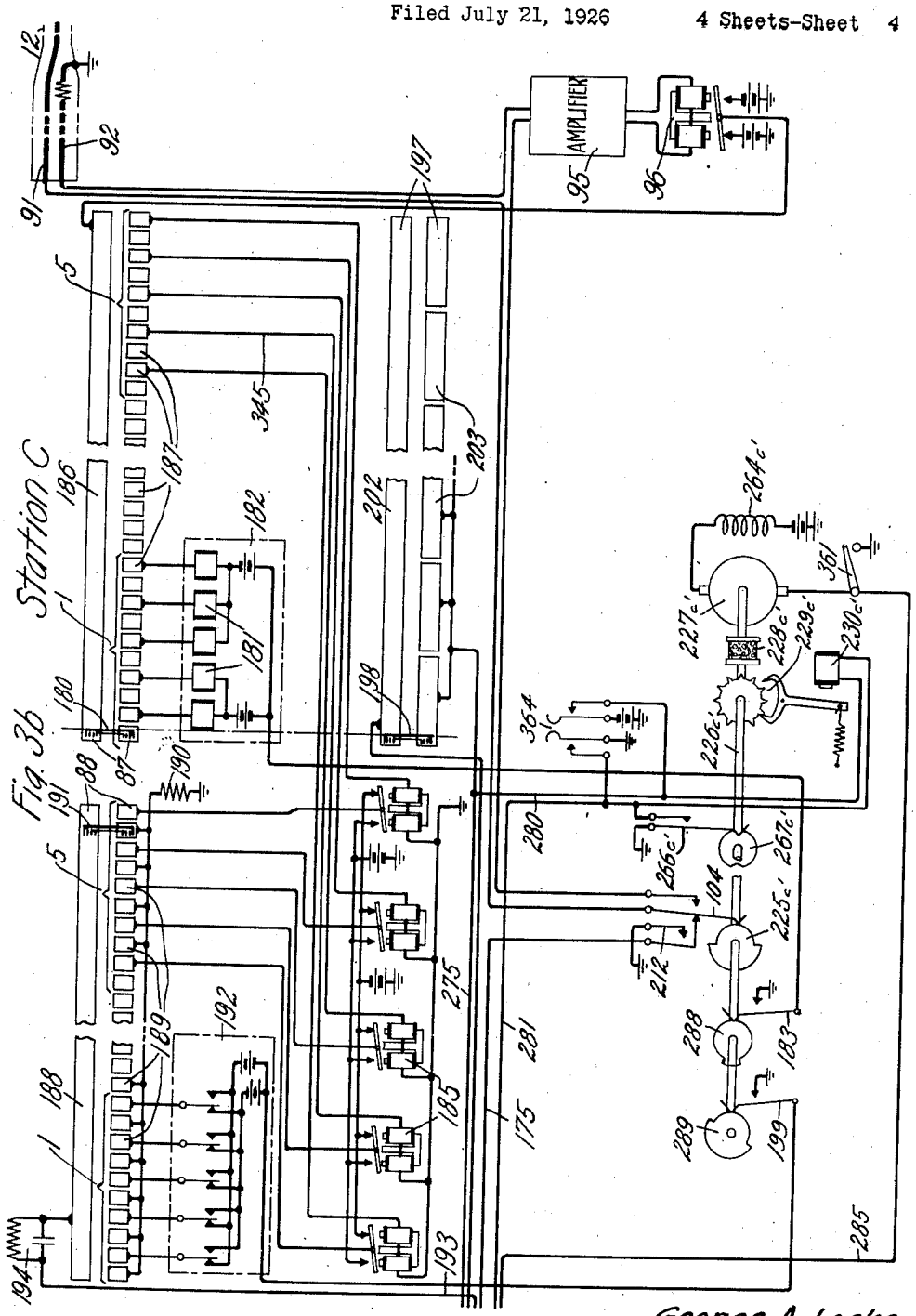
1,681,489

G. A. LOCKE ET AL

SIGNALING SYSTEM

Filed July 21, 1926

4 Sheets-Sheet 4



Inventors: George A. Locke
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Patented Aug. 21, 1928. 1,681,489

UNITED STATES PATENT OFFICE.

GEORGE A. LOCKE, OF GLEN COVE, AND HAKON H. HAGLUND, OF NEW YORK, N. Y., ASSIGNORS TO BELL TELEPHONE LABORATORIES, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK, AND THE WESTERN UNION TELEGRAPH COMPANY, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

SIGNALING SYSTEM.

Application filed July 21, 1926. Serial No. 123,861.

This invention relates to control of electrical transmission systems, especially submarine telegraph systems. In a specific aspect the invention relates to timing control mechanisms connected with automatic telegraph signaling systems, especially those adapted for operation over submarine cables.

It has been suggested that in the simplex operation of automatic telegraph signaling systems over long lines or submarine cables, the direction of transmission be automatically reversed at periodic time intervals at all stations by means of timing devices located at the respective stations.

An object of the instant invention is to control apparatus associated with an electrical transmission path, from a point remote from the apparatus, by control energy sent over the path.

A specific object of the invention is to control, by energy sent over a submarine cable, apparatus which is located at different stations on the cable and which starts the operation of timing devices such as those just mentioned.

In A. A. Clokey Patent 1,601,941, granted October 5, 1926, it is suggested that where, in signaling over a submarine cable extending between two stations simplex operation with automatic periodic reversal of the direction of transmission is adopted, there may be employed a multiplex printing telegraph system having a distributor at each station, the distributors operating synchronously, and transmit-receive switches operated automatically and periodically under control of timing devices which are located at the stations and which are driven from the distributors through clutches. In order to start operation of the timing devices at the two stations at proper relative times, engagement of the clutches is effected by prolonged current pulses initiated at one of the stations, the impulse for the distant station being transmitted thereto through the cable.

As an example of forms which the instant invention may take there is shown and described herein a specific application of the invention to a submarine cable multiplex printing telegraph system having synchronously operating distributors at the terminal and repeater stations and at each of these stations switching means operable for conditioning the system to transmit in opposite directions alternately, the switching means being under the automatic control of timing devices operated from the distributors. In the specific form of the invention shown in the drawing, in order to start operation of the timing devices at the different stations at proper relative times, each station is provided with a clutch for driving the timing device at that station from the distributor, and engagement of the clutches is effected by control impulses individual to the clutches, initiated at one of the stations. The impulse initiated for each distant station is transmitted through a sending segment of the distributor at the initiating station, (the segment being individual to the distant station as regards the sending of the control impulses and normally belonging to one of the signaling channels), and over the cable to the distant station, and through the corresponding receiving segment of the distributor there. The control impulses, in passing from the initiating station to a distant station, may pass through intermediate or repeating stations, traversing a signal channel through the latter stations, the signal repeaters at the latter stations serving to repeat control impulses.

In accordance with the invention, it is possible to control the starting of the timing mechanisms at all stations at very nearly the same time, by the set of impulses sent out over the system from one of the stations. The invention also enables this series of electrical impulses to be sent out over the system from the station which originates them in such an order as to at least partly compensate for the lag of the line or cable by permitting the timing mechanism at the most distant point to be started by the first of the series of impulses, that at the next most distant point by the next of the impulses, and so on, the mechanism at the point where the control is initiated starting from the last of the impulses.

Other objects and features of the invention will be apparent from the following description and claims. The drawing is a diagram showing the form of the invention referred to above, when Sheets 1 to 4 are horizontally arranged consecutively, with Sheet 1 at the left.

Fig. 1 shows a terminal station for the system, connected by a land line to a cable terminal station; Fig. 2 shows the cable terminal station just mentioned; and Figs, 3^a and 3^b taken together show a station at the other end of the cable just mentioned, arranged as a cable terminal station for certain of the signaling channels and as an automatic repeating or retransmitting station for the other channels.

The system shown in the drawing is arranged for five channel multiplex operation, with automatic periodic reversal of the direction of transmission for all channels substantially simultaneously. Only two channels, designated 1 and 5, are shown, the irregular breaks in the contact rings of the distributors described hereinafter indicating the presence of other channels in the system. A land line 10 extends between the west terminal station A of the multiplex circuit or system, at which multiplex terminal equipment described hereinafter is located, and the west cable terminal station B, which is a repeating station for the multiplex circuit. A submarine cable 11 extends eastwardly from the latter station to a station C which may be either a channel terminal station or a two-way repeating station as regards any of the channels, and which is therefore shown arranged as a channel terminal station for certain of the channels, as for example channel 1, and arranged to automatically repeat or retransmit signals of certain channels, for example channel 5, between cable 11 and cable 12. The cable 12 may, for example, be regarded as extending to a cable terminal station (not shown) at which the signaling channels employing cable 12 terminate in multiplex equipment of the same general character as that at station A.

At station A are shown a line relay 15 for relaying impulses received from the line 10, printers 16 and 17 of usual type terminating signaling channels 1 and 5 respectively when the system is transmitting westwardly and perforated-tape controlled transmitters 18 and 19 of usual type, for example the type disclosed in Yorke and Benjamin Patent 1,298,622, March 25, 1919, terminating channels 1 and 5 respectively when the system is transmitting eastwardly. The printers and the transmitters for the other channels are omitted from the drawing in the interest of simplicity. Printer 16 comprises five selecting magnets 20 and a printing magnet 21, the so-called sixth pulse magnet. Printer 17 comprises five selecting magnets 22 and a printer magnet or sixth pulse magnet 23. Transmitter 18 comprises five transmitter contacts 24 movable between stationary front and back contact studs connected to positive and negative battery, and a transmitter stepping magnet or so-called sixth pulse magnet 26 for stepping the transmitter tape. Similarly, transmitter 19 comprises five movable contacts 28 for connection to positive and negative battery, and a stepping magnet 29.

At station A is also a rotary distributor 30, comprising a receiving face and a sending face. The receiving face comprises a solid or common receiving ring 33 and a ring of receiving segments 34 for distributing impulses, received by the ring 33 from the relay 15, to the selecting magnets such as 20 and 22 when a brush 35 passes over the solid and segmented rings. The receiving face further comprises a printer local ring 37 and printer operating local segments 38 for controlling the sixth pulse magnets such as 21 and 23 when a brush 39 moves over the ring and segments; and the receiving face also comprises switch control rings 40 and their brush 42 which control the reversal of the direction of signal transmission in the system in a manner explained hereinafter. The rings of the distributor, and also those of the other distributors described hereinafter, are shown developed in straight lines, and of the receiving and sending segments only those corresponding to channels 1 and 5 are shown. The sending face of the distributor comprises a solid or common sending ring 50 for connection to line 10 when the system is to transmit eastwardly, and a ring of sending segments 51 for connecting the transmitter contacts such as 24 and 28 to the ring 50 when a brush 52 moves over the solid and segmented rings. The sending face further comprises a transmitter local ring 57 and transmitter operating local segments 58 for controlling the sixth pulse magnets such as 26 and 29 when a brush 59 moves over the ring and segments; and the sending face also comprises switch control rings 60 and their brush 62 which control the reversal of the direction of signal transmission in the system in a manner explained hereinafter.

At station B is a polar relay 65 operating from line 10 into multiplex equipment comprising a rotary distributor 70, the relay and the distributor constituting a rotary repeater for retransmitting, or sending out over the cable 11, the signals originating at station A. For repeating at station B the signals received over the cable which are to be transmitted on to station A, there is an amplifier 75, including a signal shaping network (not shown), and a polar relay 76 which operates directly directly from the amplifier output. The amplifier with the signal shaping network is preferably of the type disclosed in the patent granted to A. M. Curtis, No. 1,624,396, dated April 12, 1927, and the relay is preferably a polar relay.

At station C the signals of all of the signaling channels, whether or not the channels are to terminate at the station, pass through a rotary distributor which comprises receiving rings 78 and transmitting rings 79 for eastwardly directed signals and comprises

receiving rings 87 and transmitting rings 88 for westwardly directed signals. The rotary distributor operates as a terminal distributor for the signaling channels terminating at station C, such as channel 1; and the rotary distributor operates, in conjunction with an eastwardly pointed amplifier 89 and relay 90 and a westwardly pointed amplifier 95 and relay 96, as a two-way rotary repeater for the other channels, such as channel 5.

The line 10 is a two conductor line and may be of considerfable length, as for example 20 miles. The cable 11 comprises a conductor 81, and in addition, has at its west and east end portions cable sea-earth connections 82 and 83, respectively. The connection 82 comprises a conductor shown as within the cable armor, extending from the shore end of the cable to a point where the water has a considerable depth, as for example 500 feet, where it is connected through a resistance 84 to the cable armor at point 85, a conventional symbol indicating that the armor is earthed. The conductor 82 together with the impedance 84 earthed at point 85 constitutes an interference reducing circuit. The sea-earth connection 83 comprises a conductor and a resistance 86, and is similar to the connection 82. The cable 12 comprises a conductor 91, and in addition may have at its terminals sea-earth connections similar to those just described. One designated 92 is shown at the west end of cable 12. The cable sections 11 and 12 may be of any suitable type. Preferably each of their conductors comprises a copper conductor provided with a helical wrapping (not shown) of an alloy consisting principally of nickel and iron, and having high permeability at low magnetizing forces. The construction and advantages of such a loaded cable conductor are described in U. S. Patents to Buckley 1,586,874, Elmen 1,586,884, and Elmen 1,586,887, all granted June 1, 1926, and U. S. Patent to O. E. Buckley, 1,486,863, March 18, 1924. The present invention is, however, applicable also to ordinary unloaded cables used with or without balancing sea-earth connections.

For conditioning the cable circuit to transmit eastwardly, that is, in the direction from station A toward station C, mechanisms described hereinafter close to the right, as shown, switch 100 at station A, switches 101 and 102 at station B, and switch 103 at station C, and close switch 104 at station C to the left; and for conditioning the cable circuit to transmit westwardly, mechanisms described hereinafter close each of these switches to the opposite side.

Switch 100, when closed to the right, connects the west end of line 10 to a conductor 110 and a ground 111, between which the brush 52, when moved over ring 50 and segments 51, connects circuits comprising battery and the contacts of the transmitters such as 18 and 19, for transmitting marking or spacing impulses to the line 10, which correspond to the elements of any signal characters that the tape transmitters have set up. For example, the circuit for transmitter 18 extends from ground through a switch 112 controlled as described hereinafter, conductor 113, battery and contacts of the transmitter; and the circuit for transmitter 19 extends from ground through a switch 114 controlled as described hereinafter, conductor 115, battery and the contacts of the transmitter. The connections of the movable contacts of the transmitters to battery are so arranged that, switches 112 and 114 being closed, when any movable contact such as 24 or 28 is in its normal or inoperated or spacing position, in which the contacts are shown, potential of one polarity or the other is applied to the segment 51 to which that contact is connected; whereas when that contact is in its right hand or operated or marking position, it causes its connected segment 51 to receive potential of the opposite polarity. The polarity of the spacing signals sent out from the terminal distributor at station A may, for example, be positive for channels 1, 3 and 5 and negative for channels 2 and 4.

The distributor brushes of all of the distributors in the system are driven over the distributor rings in synchronism by any suitable means (not shown). It is assumed that they move from left to right over their rings as shown developed into stright lines. Brushes 52 and 59 on the transmitting face of the distributor are shown in alignment, and the sixth pulse magnet 26 is therefore shown as adapted to be connected to one of the segments 58 which is reached by brush 59 just after brush 52 has traversed the group of five sending segments 51 which represents the signaling channel 1 which terminates in transmitter 18. There are five segments 58, each individual to one channel. The circuit through which magnet 26 is operated from its local segment extends from negative battery through magnet 26 to conductor 105, thence in parallel through left hand winding of differential relay 106 and upper contacts of the differential relay and right hand winding of the differential relay, contact 108, conductor 109, contact 121 and conductor 124, thence through conductor 126 to the local segment, and thence through brush 59 and ring 57 to ground. The contact 108 is operated by the transmitter tape stop lever 129, as described in A. F. Dixon Patent 1,192,171, July 25, 1916, and controls the differential relay 106 in the circuit of the transmitter tape-stepping or sixth pulse magnet in the manner pointed out therein, to cause energization of the sixth pulse magnet, for stopping the tape feed and holding the transmitter contacts in their spacing positions. Upon the opening or closing of contact 121, which is accomplished by cam

131 in a manner described hereinafter, the transmitter contacts and the tape feed are controlled in the same manner that they would be by the opening or closing, respectively, of the contact 108. The sixth impulse magnet 29 of transmitter 19 is adapted to be connected to one of segments 58 over which brush 59 passes just after brush 52 has traversed the segments 51 representing channel 5, and while brush 52 is next traversing the segments representing channel 1. The circuit through which magnet 29 is operated from its local segment extends from negative battery through magnet 29 to conductor 105', thence in parallel through right hand winding of differential relay 106' and upper contacts 107' of the differential relay and right hand winding of the differential relay, contact 108', conductor 109', contact 121' and conductor 124', thence through conductor 126' to the local segment, and thence through brush 59 and ring 57 to ground. The contacts 108' and 121' are operated in the same manner as the contacts 108 and 121 respectively, and perform for transmitter 19 the same functions that contacts 108 and 121 respectively perform for transmitter 18, the operation of contact 121' being effected by a cam 131' actuated in a manner described hereinafter. Each of the transmitters in the system has, for controlling the circuit of its sixth pulse magnet, a differential relay and a cam switch corresponding to the differential relay 106 and the cam switch 121, although, in the interest of simplicity, the only other one of these sets of control devices which is shown is the differential relay 106' and the cam switch 121'.

Switch 100, when closed to the left, connects the west end of line 10 to the winding of line or printer relay 15. Relay 15 is a two position polar relay operating in conjunction with ring 33, segments 34 and brush 35, and switches such as 116 and 117 controlled as described hereinafter, to energize the selecting magnets of the printers such as 16 and 17 from battery. For example the selecting magnets 20 are energized over a circuit extending from battery through armature of relay 15, ring 33, brush 35, segments 34, magnets 20, battery, conductor 118, and switch 116, to ground; and the selecting magnets 22 are energized over a circuit extending from battery through armature of relay 15, ring 33, brush 35, segments 34, magnets 22, battery, conductor 119, and switch 117, to ground. Although the system has only five signaling channels and each signal character consists of only five signal elements or impulses, there are fifty of the segments 34, ten for each channel, (of which only the ten for channel 1 and the ten for channel 5 are shown). Of the ten for each channel, only alternate ones are connected to printer selecting magnets, the other five being not connected in circuit. The purpose of this construction is to permit only the center portions of the received current pulses as relayed by the line or printer relay 15 to pass into the selector magnets of the printers, so that the variations which occur in the end portions will be eliminated. These variations are the principal undesired variations which occur in cable signals and are due to capacity distortion and so-called "zero wander" which tend to cause the line relay to operate irregularly with respect to the signals sent out from the sending distributor, the reversals of the signals as received by the line or printer relay coming too early at times and too late at other times.

The brushes 35 and 39 are shown in alignment, and the sixth pulse magnet 21 is therefore shown connected to one of the segments 38 which is reached by brush 39 just after brush 35 has passed from the last of the selecting segments 34 which is associated with printer 16. There are five segments 38, each individual to one channel. The sixth impulse magnet 23 is connected to the one of segments 38 over which brush 39 passes just after brush 35 has passed from the segments 34 associated with printer 17, in channel 5, and while brush 35 is next traversing the segments 34 associated with printer 16, in channel 1.

Switch 101, when closed to the right, connects the east end of line 10 to the winding of the polar relay 65 which is a two position line relay repeating impulses received from line 10 into the multiplex distributor 70. The distributor comprises a receiving face and a sending face. The receiving face comprises a solid or common receiving ring 120 and a ring of receiving segments 122 adapted to be connected to the solid ring by movement of a brush 123 over the solid and segmented rings; and the sending face comprises a solid or common sending ring 125, and a ring of segments 127 adapted to be connected to the solid ring by movement of a brush 128 over the solid and segmented rings, and also comprises switch control rings 130 and their brush 132 which controls the reversal of the direction of signal transmission in the system in a manner brought out hereinafter. The drawing shows only those portions of the receiving rings which correspond to signaling channels 1 and 5; and shows, of the transmitting segments, only those included in channel 1 and a part of those included in channel 5. The operation of a relay such as relay 65 is subject to considerable variation in time as the wave shape of the current impulse in its winding varies, and consequently the signals outgoing from the relay reflect the distortion of the received signals by variations in the time length of individual current impulses sent out. While these variations might not actually produce errors in the received record at the distant end or terminal of the signaling channels, they tend to cause a loss in

possible transmission speed over the system taken as a whole. This loss is prevented by including in the means for repeating signals from line 10 to cable 11 the multiplex rotary distributor 70 for timing the length of the outgoing signals accurately and preventing initial distortion in the signals as transmitted from line 10 to cable 11. The rotary repeater thus prevents variation in the time length of the individual outgoing impulses due to the distortion of the signals as received by it. The signals transmitted from the rotary or regenerative repeater comprising the relay 65 and the rotary distributor 70 are more regular and perfect as to shape and timing than those transmitted from the contacts of a relay such as 65. The rotary repeater is intended to transmit to cable 11 signals which are as nearly perfect as is practicable and which have been properly curbed in a manner which will presently be described.

Switch 102, when closed to the right, connects the west end of conductor 81 of cable 11 to one end of a conductor 133, which includes a sending network represented by a condenser 134 and resistance 135 in parallel with each other, and which has its other end connected to the common sending ring 125 of distributor 70. The sending network may be of any suitable form. The preferred form is that disclosed in the application of A. M. Curtis Serial No. 56,825, mentioned above.

The armature of relay 65, operating in accordance with signaling impulses received by the relay winding from line 10, applies positive and negative battery potentials to the common receiving ring 120. The receiving segments 122 are connected to the windings of two-position polarized storing relays 141 to 145, to energize those windings when the movement of brush 123 connects the segments to the ring 120. In the case of these segments, as in the case of the receiving segments of distributor 30, although there are ten receiving segments for each signaling channel, only alternate segments are adapted to be connected in circuit, the other segments being inactive. The connection of the winding of relay 141 to the segments 122 is to the first active segment (counting from left to right in the drawing) for each signaling channel; similarly, the winding of relay 142 is connected to the second active segment of each of the five signaling channels, the winding of relay 143 to the third active segment of each channel, the winding of relay 144 to the fourth active segment of each channel, and the winding of relay 145 to the fifth active segment of each channel.

There are also fifty of the sending segments 127, ten for each signaling channel, and the armatures of relays 141 to 145 are connected to alternate ones, or even numbered ones (counting from left to right in the drawing), of these segments, the armature of relay 141 being connected to the first even numbered one of the segments 127 for each channel, the armature of relay 142 being connected to the second even numbered one of the segments for each channel, and so on in direct rotation. When the armatures operate in response to impulses in the relay windings, the stationary contacts of the armatures are connected to the even numbered segments 127 and apply to those segments positive and negative battery potentials. As brush 128 traverses the ring 125 and segments 127, these positive and negative potentials are applied from the segments to the ring and are transmitted thence through conductor 133 including the sending network, and on through the switch 102 to the conductor 81 of the cable 11. The armatures of relays 141 to 145 thus act as movable contacts of transmitters for applying to the transmitting segments 127 potentials which are transmitted eastwardly on cable 11.

In order to permit the relays 141 to 145 to operate from received impulses and settle down in their new positions before brush 128 reaches the positions for sending out the impulses as repeated by the relays, the connections from the tongues of the storing relays to the sending segments are advanced two segments in the direction of the rotation of the brushes, with respect to the receiving segments, this feature being indicated in the drawing by the relative positions in which the brushes 128 and 123 are shown. This means that as the brushes rotate the receiving brush will first pass over a segment connected to the windings of one of the storing relays causing it to operate in response to the current pulse received at that instant. After the brushes have advanced two segments the sending brush reaches the sending segment connected to the tongue of that storing relay, sending out over the cable 11 a pulse of the polarity applied to that segment by that relay. The sending and receiving brushes have a fixed angular relation with each other, being mounted on the same rotating brush arm, and, as indicated above, the connections to the sending segments are made in the same order of rotation as the receiving segments so as to send out the signal elements or impulses in the same sequence as they were received. The rotary repeater introduces a definite fixed time delay or lag in repeating signals, which is added to the lag produced by the line 11 and the cable sections such as 11 and 12.

In sending current pulses out over a cable, if the outgoing signal pulses are made short and sharp and the cable is earthed at the sending point for a short time after each pulse, the received signals are much less distorted. For this so-called "curbing", a combination which gives good results from a shaping standpoint is that where time intervals occupied by the outgoing pulses alternate with time intervals which are equal to the duration

of the pulses and throughout which the cable is earthed at the sending point. With this so-called 50% marking, the pulses of marking and spacing polarity are each equal to the intervals of earthing. The segments of the distributor 70 are shown arranged to send out pulses of this nature, the odd numbered ones of the segments 127 being equal in length to the even numbered ones, and being all connected to earth through a resistance 155 so that in sending eastwardly over cable 11, when brush 128 contacts with any odd numbered one of the segments 127 the conductor 81 of cable 11 is earthed through a circuit extending from conductor 81 through switch 102, conductor 133 and the sending network, ring 125, brush 128, the segment 127 in contact with the brush, and resistance 155.

In the transmission of the multiplex signals over a long submarine cable such as 11 it is desirable to keep the positive and negative impulses as evenly balanced as possible in order to prevent distortion in the received signals with its accompanying zero-wander. With a 5-channel system the standard method of inverting the polarities of marking and spacing batteries in each channel causes a predominance of one polarity over the other on the average and when certain combinations are set up in the transmitters permits an exaggerated unbalance of polarities to be imposed on the cable. In order to cut down the probability of heavily unbalanced conditions occurring, the system has been arranged to invert the polarities of marking and spacing batteries between the second and third impulses of each channel signal combination when sent out over the cable 11. The polarities of marking and spacing on the five channels then become, for example, as follows:

Positive.

Marking:
Pulses 3, 4, 5 on channels 1, 3 and 5.
Pulses 1, 2 on channels 2 and 4.

Negative.

Pulses 1, 2 on channels 1, 3 and 5.
Pulses 3, 4, 5 on channels 2 and 4.

Positive.

Spacing:
Pulses 1, 2 on channels 1, 3 and 5.
Pulses 3, 4, 5 on channels 2 and 4.

Negative.

Pulses 3, 4, 5 on channels 1, 3 and 5.
Pulses 1, 2, on channels 2 and 4.

This splitting of the channels and inverting of polarities has been done in the rotary repeater at station B by reversing the polarities of battery connected to the contacts of the storing relays between the second and third relays, as shown in the drawing. The signals are sent out from the terminal distributor at station A in accordance with the standard arrangement and are repeated onto the cable 11 with the polarities of the third, fourth and fifth impulses of each channel inverted.

Similarly, westwardly directed signals in cable 11 have the polarities of the third, fourth and fifth impulses of each channel inverted from the polarities which they would have were their transmission over the cable in accordance with standard practice. To, in effect, rectify the inverted polarities of the third, fourth and fifth impulses of each channel combination of the signals received at station A, the common connections from the selector magnets of each of the printers are split between the second and third magnets of the printer and carried to opposite poles of battery. That is, the first and second magnets of the printer 16 are connected to the positive pole, and the third, fourth and fifth magnets to the negative pole. For the printer of the second channel (not shown) the first and second magnets are connected to the negative pole and the third, fourth and fifth to the positive pole. The printers for the third channel (not shown) and the fifth channel are connected in the same way as the printer 16, and that of the fourth channel (not shown) in the same way as the printer for the second channel. This, in effect, rectifies the polarities of the last three impulses of the received signals of each channel. The right hand stationary contact of relay 15 is connected to positive battery, and the left hand stationary contact of the relay is connected to negative battery. Therefore, when the relay closes its right hand contact, as shown, the selector magnets connected to positive battery cannot become energized but any other selector magnet will be operated if its receiving segment is engaged by brush 35 and its control switch such as 116 or 117 is closed. Similarly, when the relay closes its left hand contact the selector magnets connected to negative battery cannot become energized but any other selector magnet will be operated if its receiving segment is engaged by brush 35 and its control switch such as 116 or 117 is closed.

Switch 102, when closed to the left, connects cable conductor 81 to the input of amplifier 75, to transmit to the amplifier westwardly directed signals coming into station B over cable 11. The signals are amplified and corrected for distortion in the amplifier, and then pass into the winding of the relay 76. Switch 101 being closed to the left, relay 76 retransmits the signals to station A over line 10. The relay prevents the amplifier from unbalancing the line 10 with respect to earth, thus reducing deleterious effects of extraneous electric fields to which line 10 may be subjected, as disclosed in A. M. Curtis Patent 1,639,929, granted Aug. 23, 1927, entitled

Signaling systems. The signals are distorted so little by their passage over a comparatively short land line such as 10, that no rotary repeater is provided at station B for westwardly directed signals. Consequently, the rotary repeater at station B is a one-way rotary repeater.

Switch 103, when closed to the right, connects cable conductor 81 to the input of amplifier 89, to transmit to the amplifier eastwardly directed signals coming into station C. The amplifiers 89 and 95 may be, for example, like the amplifier 75. The signals pass from amplifier 89 into the winding of relay 90, which is a two position polar relay operating in conjunction with the pair of rings 78 and their brush 160 to energize storing relays 163, and operating in conjunction with the brush and rings, and with a switch 156 actuated as described hereinafter, to energize the selecting magnets 161 of a printer 162. This operation is substantially like the operation of selector magnets 20 and storing relays 141 to 145, the pair of rings 78 comprising a solid or common receiving ring 164 and a ring of segments 165 similar to the solid and segmented receiving rings, respectively, at stations A and B. The pair of rings 79 comprise a solid or common sending ring 166 and a ring of segments 167, these being similar to the sending rings at station B, and the odd numbered ones of the segments 167 being earthed through a resistance 168 which corresponds to the resistance 155. A brush 169 is movable over rings 79 to connect segments 167 to ring 166. A transmitter 170, similar to transmitter 18, has its movable contacts connected to the even numbered sending segments of channel 1 and the storing relays 163 have their tongues connected to the even numbered sending segments of channel 5, just as the tongues of the storing relays 141 to 145 at station B are connected to the even numbered sending segments 127 of each of channels 1 to 5.

Switch 104, when closed to the left, connects the west end of conductor 91 of cable 12 to one end of a conductor 175, which includes a sending network 176 similar to the network 134, 135 of station B, and which has its other end connected to the common sending ring 166.

The stationary contact studs of transmitter 170 are in circuit with battery and a switch 177 actuated as described hereinafter, and, with switch 177, closed, as brush 169 traverses ring 166 and segments 167 positive and negative battery potentials can be applied to the segments from transmitter 170 and storing relays 163 and transmitted to the ring 166 and thence through the conductor 175 including the sending network, and on through the switch 104 to the conductor 91 of the cable 12, for transmission eastwardly thereover.

Switch 104, when closed to the right, connects cable conductor 91 to the input of amplifier 95, to transmit to the amplifier westwardly directed signals coming into station C. The signals pass from the amplifier into the winding of relay 96, which is like relay 90 and operates in conjunction with the pair of rings 87 and their brush 180 to energize storing relays 185, and operates in conjunction with the brush and rings, and with a switch 183 actuated as described hereinafter, to energize the selecting magnets 181 of a printer 182. The operation of magnets 181 and relays 185 is like the operation of selector magnets 161 and storing relays 163, the pair of rings 87 comprising a solid or common receiving ring 186 and a ring of segments 187, similar to the solid and segmented receiving rings 164 and 165. The pair of rings 88 comprise a solid or common sending ring 188 and a ring of sending segments 189, and is similar to the pair of rings 78, the odd numbered ones of segments 189 being earthed through a resistance 190 which corresponds to the resistance 168. A brush 191 is movable over rings 88 to connect segments 189 to ring 188. A transmitter 192 similar to the transmitter 170, has its movable contacts connected to segments 189 of channel 1 and the storing relays 185 have their tongues connected to the sending segments 189 of channel 5, just as the corresponding parts of transmitter 170 and relays 163 are connected to segments 167.

Switch 103, when closed to the left, connects the east end of cable conductor 81 to one end of a conductor 193, which includes a sending network 194 similar to the network 176, and which has its other end connected to the common sending ring 188.

The stationary contact studs of transmitter 192 are in circuit with battery and a switch 199 actuated as described hereinafter, and, with switch 199 closed, as brush 191 traverses ring 188 and segments 189 positive and negative battery potentials can be applied to the segments from the transmitter 192 and storing relays 185 and transmitted to the ring 188 and thence through the conductor 193 including the sending network 194, and on through the switch 103 to the conductor 81 of cable 11, for transmission westwardly thereover.

The polarities of battery connected to the marking and spacing contacts of transmitters 170 and 192 are reversed between the second and third contacts of each transmitter, so that the signals are sent out from the transmitter with the polarities of the third, fourth and fifth impulses of each channel signal combination inverted. This splitting of the channels and inverting of polarities is for the purpose pointed out in the description above of stations A and B. Such splitting of channels and inverting of polarities is not required

of the storing relays 163 and 185, since the signals incoming to these relays are signals which have already been so treated.

The sending brush 169 and the receiving brush 160 are shown in different relative positions along the segmented rings 167 and 165, for the same reason that the sending and the receiving brushes at station B are shown thus relatively displaced. Brushes 191 and 180 are likewise shown relatively displaced. The printing magnets and the transmitter tape stepping magnets, and the printer and transmitter local rings for generating the so-called sixth pulses for operating these magnets, are omitted from the showing of station C, in the interest of simplicity.

The rotary distributor comprising rings 78, 79, 87 and 88 also comprises a pair of rings 195 and their brush 196, and a pair of rings 197 and their brush 198, these rings and brushes 195 to 198 controlling reversal of the direction of signal transmission in the system, in a manner brought out hereinafter. The pair of rings 195 comprises a solid ring 200 and a ring of segments 201. Brush 196 is movable over this pair of rings to connect the segments to the solid ring. The pair of rings 197 comprise a solid ring 202 and a ring of segments 203. Brush 198 is movable over this pair of rings to connect the segments to the solid ring.

When during the changing of station B from its condition for sending signals to cable conductor 81 to its condition for receiving signals from that conductor, switch 102 is operated from its right hand to its left hand position to disconnect that conductor from conductor 133 leading from common sending ring 125 and connect the conductor 81 to the input circuit of amplifier 75, an auxiliary contact 210 on the switch 102 momentarily earths the contact connected to the conductor 81, to momentarily earth conductor 81 during the time it is being disconnected from the sending ring 125 and before it is connected to the input circuit of amplifier 75. This short earthing period is sufficient to considerably reduce earth currents which might flow through the input circuit of amplifier 75 between conductor 81 and the earth at 85 upon the connection of conductor 81 to that input circuit. These earth currents, if excessive, would tend to paralyze the amplifier.

Similarly, when conductor 81 is being disconnected from conductor 193 leading from sending ring 188 before being connected to the input of amplifier 89, an auxiliary contact 211 of switch 103 momentarily earths the cable conductor 81 to protect amplifier 89.

Similarly, when conductor 91 is being disconnected from conductor 175 leading from sending ring 166 before being connected to the input of amplifier 95, an auxiliary contact 212 of switch 104 momentarily earths the cable conductor 91 to protect amplifier 95.

The send-receive switch 100, at station A, is operated by a cam 225 on a switch-operating cam shaft 226 which is driven in clockwise direction by an electric motor 227. Half of the periphery of the cam is depressed, and the switch has a cam follower bearing on the periphery, the switch being closed to the left when the cam follower is in the depression but being closed to the right when the cam follower bears on the remaining or raised portion of the periphery. A slip-clutch 228 is interposed between the motor and the shaft 216 so that an escapement 229 operated by a stepping magnet 230 can control and regulate the motion of the cam shaft. The escapement magnet 230 is controlled by the conjoint action of timing switches 235, 236 and 237 of a timing device 240, distributor rings 40 and 60, and a transfer switch 242 which is operated by a transfer cam 241 on the cam shaft 226 to transfer the control from rings 40 to rings 60 and vice versa for a purpose explained hereinafter. The circuit of magnet 230 for starting the magnet stepping under control of rings 40 and 60 and their brushes, extends from negative battery through magnet 230, a conductor 243, thence to the right hand contact of switch 242 either through conductor 244, lower ring 40, brush 42, upper ring 40, conductor 245 and left hand contact of switch 242 or through conductor 246, lower ring 60, brush 62, upper ring 60, conductor 247 and middle contact of switch 242, in accordance with the position of cam 241, and thence through conductor 250 and the right hand contacts of timing switches 235, 236 and 237, to ground. A locking circuit for the stepping magnet is described hereinafter, which shunts the path through the right hand contacts of switches 235, 236 and 237, to maintain the magnet stepping for a predetermined period, regardless of the opening of that path.

The timing device 240 comprises cams 251, 252 and 253 for operating switches 235, 236 and 237, respectively, and gearing for operating the cams from the drive shaft 254 of the distributor 30 through a clutch 255. The clutch is normally held in engagement by a spring 256 although shown as held is disengaged position by a latch 257. The latch is controlled by a clutch releasing magnet 258 for starting the cams 251, 252 and 253 upon energization of magnet 258 in a manner described hereinafter. The clutch shaft may be driven at a speed of, for example, 105 R. P. M. when distributor shaft 254 is rotating at the speed which corresponds to the normal transmisison speed of the associated cable circuit. Through a gear train 259 the clutch shaft drives a shaft 260 at a speed of, say, 2 R. P. M. Through gear trains 261, 262 and 263, shaft 260 drives the cams 251, 252 and 253, say clockwise at speeds of $\frac{1}{2}$ R. P. M., 1 R. P. M. and 4 R. P. M., respectively. Each

of the cams 252 and 253 has a depressed portion in its periphery, and the cam 251 in the specific form shown has in its periphery, two depressions which are diametrically opposite each other. The switches 235, 236 and 237 have cam followers which bear on the peripheries of the cams 251, 252 and 253, respectively, the switches being closed when their respective cam followers are in the depressions, but being opened when their respective cam followers are on the remaining or raised portions of the cam peripheries.

With clutch 255 engaged, switch 237 will close four times each minute, each period of closure lasting $\frac{1}{15}$ of a minute or about 4 seconds; switch 236 will close once each minute, each period of closure lasting, say, 15 seconds; and, when cam 251 has the specific form shown, switch 235 will close once every 6 minutes, each period of closure lasting ½ minute. This specific form of cam 251 is intended to cause the system to reverse the direction of signal transmission over the cable circuit once every six minutes. This cam, or what amounts to the same thing, other cams (not shown) which may be caused to function in its stead in the system, may have other forms, with depressed portions separated by raised portions of any suitable length, to represent any suitable time periods of traffic in either direction. If desired, the alternate spacings between the depressions around the periphery may be made unequal, for taking care of traffic which is heavier in one direction than in the other in the general manner disclosed in U. S. Patent to Clokey 1,601,941, granted October 5, 1926, mentioned above.

The relative angular positions of cams 251, 252 and 253 on their shafts is such that during each period of closure of switch 235 there will be a period in which both of the switches 236 and 237 are in the closed condition, or in other words, a period of coincident closure of switches 235, 236 and 237. Therefore, the above traced circuit extending through stepping magnet 230 for starting the stepping of that magnet, is closed, and starts that magnet stepping. Moreover, when magnet 230 starts stepping, the motor 227 has already started and accelerated to normal speed; for the relative angular positions of cams 251, 252, and 253 on their shafts is such that the period of coincident closure of switches 235, 236 and 237 begins while switches 235 and 236 are already in closed condition and have been in closed condition for the length of time which the motor requires to accelerate, and the circuit of the motor is complete whenever these switches 235 and 236 are both in closed condition. This motor circuit extends from negative battery through the motor field 264, the motor armature, a conductor 265, and the left hand contacts of switches 235 and 236 in series, to ground. Whenever this circuit has been closed, the motor starts and when the switch advances one step a locking circuit is closed for the stepping magnet 230 at a switch 266, this switch being operated by a cam 267 on shaft 226. This cam has two short depressions at diametrically opposite points on its periphery, and the switch 266 has a cam follower pressing on the cam and is maintained closed by the remaining or raised portions of the periphery except when the cam follower is at one of these two points. Upon closure of the motor circuit through switches 235 and 236 and consequent establishment of the locking circuit for the stepping magnet by switch 266, the stepping magnet continues to step due to the impulses generated by rings 40 and brush 42 or rings 60 and brush 62, until the shaft 226 has moved through 180° from its starting position, and then the stepping magnet and consequently the shaft 226 stops due to the opening of switch 266, the relative angular positions of cams 251, 252 and 253 on their shafts being such that the stepping circuit through switches 235, 236 and 237 has opened while the shaft was turning through the 180°. The locking stepping circuit through switch 266 extends from conductor 250 through switch 266 to ground, thus shunting that part of the stepping circuit traced above which extends from conductor 250 through the right hand contacts of switches 235, 236 and 237 to ground. The relative angular positions of cams 251 and 252 on their shafts are such that the motor circuit through switches 235 and 236 remains closed at least until magnet 230 stops stepping, that is, until shaft 226 has turned through 180° from its starting position, and then or shortly thereafter the motor circuit is opened at switch 236 or 235, thus avoiding unnecessary running of the motor and slipping of clutch 228.

The shaft 226 is shown in the position of rest which it occupies when the send-receive switch 100 is in condition for transmission eastwardly from station A, or in other words, the position which it would occupy after completing the half revolution described just above, provided that half revolution was begun when the switch 100 was in condition for transmission westwardly, that is, in condition for reception by station A. Throughout the first part of such half revolution, or, in other words, throughout that part of the half revolution in which station A was connected to the line for receiving, the transfer switch 242 maintained the stepping magnet under control of the rings 40 and brush 42 of the receiving face of distributor 30; and then when cam 225 shifted the send-receive switch 100 to the send position, the transfer cam 241 allowed the transfer switch 242 to transfer control of the stepping magnet 230 from the receiving face of the distributor to the rings 60 and brush 62 of the sending face. Thus, when the station is being changed from a

condition for transmission in one direction in the system to a condition for transmission in the other direction in the system, the control of the stepping of shaft 226 is performed by the distributor face active in transmitting signals in the one direction, until the instant at which the connection of the line to the station becomes proper for transmission which is to pass in the other direction in the system, and at that instant the control of the stepping of shaft 226 is transferred to the other distributor face, which is then about to become the distributor face active in the transmission of signals in the system. In this way there is obtained accuracy in the timing, with relation to the signal impulses, of various switching operations which forms steps in the operation of changing the station from the receiving to the sending condition or vice versa. These steps may include, for example, the opening and closing, as described hereinafter, of contacts 112, 114, 116 and 117 in the circuits of the selecting magnets of the printers and in the circuits of the tape operated contacts of the transmitters, the opening and closing, as described hereinafter, of the contacts such as 121 and 121′ in the circuits of the sixth pulse magnet of the transmitters, as well as the operation of switch 100 itself in switching the line 10 from the winding of the receiving relay 15 to ground and the common sending ring 50 or vice versa.

The lower one of the stepping rings 40 is divided into ten segments. However, the ring operates magnet 230 as though the ring consisted of two segments equal to each other in length. The sixth to the tenth of the segments (counting from left to right in the drawing) are not connected in circuit, and the first five are connected together and act, as regards operation of magnet 230, as a single long segment connected to conductor 244. Thus, in generating pulses of current for operating the magnet 230, rings 40 and brush 42 cause the magnet to receive one current pulse during and throughout each ½ revolution of the brush, and cause the magnet circuit to be open during and throughout the other half of each revolution of the brush. Rings 60 and brush 62 operate likewise. Thus, the shaft 226 takes two steps, or turns through an angle equal to 360° divided by the number of the teeth of the escapement wheel of escapement 229, for each revolution of the distributor. There may be, for example, thirty teeth (though for clearness the escapement wheel in the drawing is shown as having fewer teeth), in which case thirty revolutions of the distributor, and thirty steps of the shaft 226 will be required for each ½ revolution of shaft 226. The ½ revolution of shaft 226 may require a time of the order of six seconds, by way of example. During the first three of these six seconds required for the complete changeover in the condition of the station from say the receiving to the sending condition, there is accomplished the opening of switches 116 and 117 in a manner about to be described. At the end of the three seconds, the switch 100 moves from its left-hand closed position to its right-hand closed position and the switch 242 transfers control of the stepping magnet from rings 40 to rings 60, and during the next three seconds the closing of switches 112 and 114 is accomplished in a manner about to be described.

Shaft 226 drives a shaft 269 through a gear train 268 having a 1 to 1 speed ratio. Cams 131, 191′, 279, 272, 273 and 274 on shaft 269, operate switches 121, 121′, 112, 114, 116 and 117, respectively. The operation of the last four of these switches is in the order in which they are here named, when shaft 226 is being turned clockwise from its present position through 180°. Thus, when the station is being changed from the transmitting to the receiving condition, transmitter 18 is removed from circuit, thereafter transmitter 19 is removed from circuit, subsequently the transmit-receive switch 100 is operated from the transmit position to the receive position, thereafter printer 16 is connected in circuit, and subsequently printer 17 is connected in circuit. The switch 112 controls the transmitter (not shown) for channel 2 in the same manner in which it controls the transmitter 18 for channel 1; the switch 114 controls the transmitters (not shown) for channels 3 and 4 in the same manner in which it controls the transmitter 19 for channel 5; the switch 116 controls the printer (not shown) for channel 2 in the same manner in which it controls printer 16 for channel 1; and the switch 117 controls the printers (not shown) for channels 3 and 4 in the same manner in which it controls the printer 17 for channel 5. As indicated above, the transmitter for each channel has a cam and a switch corresponding to the cam 131 and switch 121.

When station A is being changed from the receiving to the transmitting condition, first the printers for channels 1 and 2 will be cut out of circuit by switch 116, then the printers for channels 3, 4 and 5 will be cut out of circuit by switch 117, then the switch 100 will be operated to the left, then the transmitters for channels 1 and 2 will be cut in circuit by switch 112; and finally the transmitters for channels 3, 4 and 5 will be cut in circuit by switch 114.

At a distant terminal station for one or more of the channels of the system, such as station C or a station lying to the east of station C and terminating the system, there is apparatus, similar to that described above for station A, for periodically changing the condition of the station from the condition

for transmission in one direction in the system to the condition for transmission in the opposite direction. This changing includes periodically changing the channel terminations at the station from a sending to a receiving condition and vice versa; and where a channel is longitudinally divided into two separate signaling circuits and so has two channel terminations at the same station, as in the case of the two terminations of channel 1 at station C, one of the two terminations undergoes a change from the receiving condition to the sending condition while the other is undergoing the change from the sending to the receiving condition, and vice versa. This simultaneous changing is effected, as will now be described for station C by way of example, by having at the station two direction-control switch-operating cam shafts 226c and 226c′ such as the cam shaft 226 of station A, one shaft functioning to operate switches including switches 103, 177 and 156 and the other functioning to operate switches including switches 104, 183 and 199, and both controlled by a timing device 240c such as the timing device 240 of station A and by a transfer switch 242c, stepping rings 195 and stepping rings 197 corresponding to the transfer switch 242, stepping rings 40 and stepping rings 60 of station A.

The cable switch or direction control switch 103 at station C (which is the send-receive switch for that signaling circuit of channel 1 extending west from station C and is a cable switch or direction control switch for transmission in each of channels 1 to 5) corresponds in structure and function to the send-receive switch 100 at station A, and is operated from shaft 226c by a cam 225c. Elements at station C designated by reference characters having "c" or "c′" appended, correspond in structure and function to elements at station A designated by the same reference characters without such appendage. The transfer switch 242c is operated from shaft 226c by a cam 241c. The shaft 226c is operated by a motor 227c, clutch 228c, and escapement 229c, the magnet for operating escapement 229c being designated 230c. A locking switch 266c for the circuit of magnet 230c is operated from shaft 226c by a locking cam 267c.

The cable switch or direction control switch 104 at station C (which is the send-receive switch for that signaling circuit of channel 1 extending east from station C and is a cable switch or direction control switch for transmission in each of channels 1 to 5) corresponds in structure and function to the send-receive switch 100 at station A, and is operated from shaft 226c′ by a cam 225c′. Shaft 226c′ is operated by a motor 227c′, clutch 228c′ and escapement 229c′, the magnet for operating the escapement being designated 230c′. A locking switch 266c′ for the circuit of magnet 230c′ is operated from shaft 226c′ by a locking cam 267c′.

The circuit of magnet 230c for starting the magnet stepping under control of rings 195 and 197 and their brushes, extends from negative battery to the left hand spring of switch 242c, thence to a conductor 270 either through middle spring of switch 242c, conductor 271, distributor ring 202, brush 198, ring 203, and conductor 275 or through right hand spring of switch 242c, conductor 276, distributor ring 200, brush 196, ring 201, and conductor 277, in accordance with the position of cam 241, and from conductor 270 through magnet 230c, conductor 278, middle contact of switch 235c, left hand contact of switch 236c and switch 237c to ground.

The circuit of magnet 230c′ for starting the magnet stepping under control of rings 195 and 197 and their brushes, extends from negative battery to conductor 275 over the paths just traced for the circuit of magnet 230c, and from conductor 275 through conductor 280, magnet 230c′, conductor 281, left hand contacts of switches 235c and 236c, and switch 237c to ground.

The circuit for motor 227c extends from negative battery through motor field winding 264c, the armature of the motor, conductor 282, and right hand contacts of switches 236c and 235c in series, to ground. Whenever this circuit has been closed, the motor starts, when the shaft 226c advances one step, the operation of cam 267c, closes a locking circuit for the stepping magnet 230c at switch 266c. This locking circuit extends from conductor 278 through switch 266c to ground, thus shunting that part of the stepping circuit traced above which extends from conductor 278 through switches 235c, 236c and 237c to ground.

The circuit for motor 227c′ extends from negative battery through motor field winding 264c′, the motor armature, conductor 285, and right hand contacts of switches 236c and 235c in series, to ground. Whenever this circuit has been closed, the motor starts and, by the operation of cam 267c′ closes a locking circuit for the stepping magnet 230c′ at switch 266c′. This locking circuit extends from conductor 281 through switch 266c′ to ground, thus shunting that part of the stepping circuit traced above which extends from conductor 281 through switches 235c, 236c and 237c to ground.

When station C is being changed from the condition in which it should be while the system is transmitting eastwardly to the condition in which it should be while the system is transmitting westwardly, or, in other words, when station C is being changed from a condition in which the rings 78 and the rings 79 are the active receiving and sending rings to a condition in which the rings 87 and the rings

88 will be the active receiving and sending rings, the stepping magnets 230e and 230e' are first under control of the stepping rings 195 on the distributor face comprising the receiving rings 78 and the transmitting rings 79, and then, as rings 78 and 79 cease to be the active receiving and transmitting rings and the rings 87 and 88 become the active receiving rings and transmitting rings, cam 241e causes switch 242e to transfer control of the stepping magnets 230e and 230e' to stepping rings 197 on the distributor face which comprises the receiving rings 87 and the transmitting rings 88 as these rings 87 and 88 become the active receiving and sending rings. Similarly, at each instant throughout the period during which the station C is being changed from its condition for westwardly directed transmission in the system to its condition for eastwardly directed transmission in the system, the stepping magnets 230e and 230e' are under the control of the pair of stepping rings on the same distributor face as the receiving and sending rings which happen to be active at the instant. In this way, there is obtained accuracy in the timing, with relation of the signal impulses at station C, of various switching operations which form steps in the operation of changing the condition of the station from that for transmission in one direction in the system to that for transmission in the opposite direction in the system, and vice versa. These steps include, by way of example, the operation of switches 156, 177, 183 and 199, the operation of switches (not shown) corresponding to switch 121' and also the operation of switches (not shown) for switching the amplifiers 89 and 95 in circuit in several steps as disclosed in a copending application of A. M. Curtis, Serial No. 119,536, filed June 30, 1926. This switching of the amplifier in steps is to avoid paralyzing the amplifier by the voltage surges incident to switching the cable to the input of the amplifier after sending signals out over the cable. The switches 156 and 177 are operated by cams 286 and 287 on a shaft 269e driven by shaft 226e through a gear train 268e having a 1 to 1 speed ratio. The switches 183 and 199 are operated by cams 288 and 289 on shaft 226e'. Switch 177 may control any transmitters of channels 1 and 2 connected to segments 167. If any of channels 3 to 5 have transmitters connected to segments 167, another switch (not shown) operated from shaft 269e will be provided to control those transmitters, so that the transmitters connected to segments 167 will be switched in two groups, as is described above for the transmitters at station A. Switch 156 may control any printers of channels 1 and 2 connected to segments 165. If any of channels 3 to 5 have printers connected to segments 165, another switch (not shown) operated from shaft 269e will be provided to control those printers, so that the printers connected to segments 165 will be switched in two groups, as is described above, for the printers at station A. Similarly, switches 183 and 199 may each control more than a single printer or transmitter connected to segments 187 or 189, and additional switches may be provided for similarly controlling still other printers and transmitters connected to those segments. The operation of the apparatus at station C for changing the condition of the station from that suitable for transmission in one direction in the system to that suitable for the opposite direction and vice versa, being similar in general to the operation of the direction control apparatus at station A described above, will be apparent without further description other than to note again that the operation of switches 103 and 104 of this direction control apparatus at station C changes the connections of the two-way rotary repeater to the circuit from the condition for automatically repeating in one direction to that for automatically repeating in the opposite direction, and vice versa, so that the operation of the direction control apparatus at station C conditions the station for reversal of the direction of transmission not only with regard to the signaling channels which have one or more terminations at the station, such as channel 1, but also with regard to the channels, such as channel 5, in which signals are automatically repeated through the station.

Switch 102 at station B is a polarized relay. As noted above, operation of switches 101 and 102 at station B condition that station for reversal of the direction of transmission through the station. The means for periodically reversing the positions of each of these switches is similar to the means described above for operating the send-receive switch 100 at station A and the cable change-over switches 225e and 225e' at station C, and comprises a motor 227b driving a cam shaft 226 through a slip-clutch 228b, a cam 225 mounted on shaft 226b and operating switch 101, a cam 225b' mounted on shaft 226b and operating a switch 102' which controls relay 102, an escapement 229b controlling shaft 226b and having a stepping magnet 230b controlled by stepping rings 130 and brush 132, a timing device 240b for controlling the circuit of motor 227b and stepping magnet 230b, and a cam 267b mounted on shaft 226b and operating a switch 266b which controls a locking circuit for the stepping magnet. Elements at station B designated by reference characters having "b" or "b'" appended correspond in structure and function to the elements of station A designated by the same reference characters without such appendage.

The circuit of magnet 230b for starting the magnet stepping under control of rings 13 and brush 132 extends from negative battery through magnet 230b, conductor 295, low

ring 130, brush 132, upper ring 130, conductors 296 and 297, switch 237[b], and left hand contacts of switches 236[b] and 235[b] in series, to ground.

The circuit for motor 227[b] extends from negative battery through the motor field 264[b], the armature of the motor, conductor 298, and right hand contacts of switches 236[b] and 235[b], to ground. Whenever this circuit has been closed, the motor 227[b] starts and, by operation of cam 267[b], closes a locking circuit for the stepping magnet 230[b] at switch 266[b]. This locking circuit extends from conductor 297 through switch 266[b] to ground, thus shunting that part of the stepping magnet circuit traced above which extends from conductor 297 through switches 237[b], 236[b] and 235[b] to ground. The operation of the apparatus at station B for changing the condition of the station from that suitable for transmission in one direction in the system to that suitable for transmission in the opposite direction, and vice versa, being similar in general to the direction control apparatus at stations A and C described above, will be apparent without further description. The amplifier 75 may be switched in circuit in several steps, by switches (not shown) operated from cams on shaft 226[b], as is mentioned above for the amplifiers 89 and 95 at station C.

As stated above, the distributors at the different stations of the system are operated in synchronism. That is, the distributor brushes are rotating at the same angular velocity and each brush is in time phase with the signals passing through it, the angular displacement of each receiving brush with respect to each distant brush sending signals thereto representing at each instant the time required for a transmitted signal to traverse the circuit between the two brushes.

With the distributors so operating, and with the system in the condition shown in the drawing, the system operates to transmit signals, sent by transmitters such as 18 at station A, from station A eastwardly over line 10 and through the rotary repeater at station B, and over cable 11 to station C. At station C, these signals in all of the signaling channels 1 to 5 pass through amplifier 89 and relay 90, and the signals in certain of the channels, such as channel 1, are printed by printers such as printer 162 and the signals in other channels such as channel 5, are automatically transmitted through rings 78, storing relays 163 and rings 79 and eastwardly over cable 12 to a terminal station (not shown) where they may be printed by printers such as printer 162. While station A is thus sending signals, station C may be originating other signals, at transmitters such as transmitter 170, and transmitting the latter signals eastwardly, in channels such as channel 1 which have two terminations at station C. These latter signals may be transmitted over cable 12 to a terminal station (not shown) where they may be printed by printers such as printers 162.

To cause the direction of transmission in the system to be periodically reversed automatically, the direction control apparatus at each station is started by energizing the clutch control magnets such as 255, 255[b] and 255[c] in a manner, described hereinafter, such that engagement of the clutches at all of the stations is effected substantially simultaneously.

When the clutches have thus engaged, the timing devices such as 240, 240[b] and 240[c] have accordingly started, and the consequent operation of the motor driven cam shafts such as 226, 226[b], 226[c] and 226[c'] causes each of the stations to be periodically changed as described above, from a condition for transmission in one direction in the system to a condition for transmission in the other direction in the system and vice versa. The time intervals between the changes at any station are equal to those at each of the other stations, since the cams, such as 251, 251[b] and 251[c] in use at any one time, are all alike and the distributors are operating synchronously. Therefore, in view of the above specified relative starting times of the timing mechanism the local and line connections at each station will be changed, from the condition for transmission in one direction to that for transmission in the other direction and vice versa, in synchronism with the changes in the direction of the signals at the station. At each station, the proper relative timing as described above of the different switching steps involved in changing the station from the condition for transmission in one direction to the condition for transmission in the other direction is obtained by properly shaping the cams on the shafts such as 226, 269, 226[b], 226[c], 269[c] and 226[c'] and properly adjusting the relative angular positions of those cams upon their shafts. As noted above, where the cams such as 251, 251[b] and 251[c] are of the form indicated the direction of transmission is reversed every six minutes.

When the system has been changed from the condition in which it is shown, that is, the condition for transmission eastwardly, to the condition for transmission westwardly, by the turning of each of the shafts such as 226, 269, 226[b], 226[c], 269[c] and 226[c'] through 180° from the positions in which they are shown, signals will be transmitted westwardly over cable 12 to station C from a station (not shown) which lies east of station C and which may be, for example, the station terminating the system at its east end. These signals may originate at the latter station in transmitters, such as the transmitters 18 and 19 of station A, terminating channels 1 to 5 at their east end. Upon arriving at station C all of these signals pass through amplifier 95 and relay 96, and the signals in certain of the channels, such as channel 1, are printed by printers such

as printer 182 and the signals in other channels, such as channel 5, are automatically transmitted through rings 87, storing relays 185 and rings 88 westwardly over cable 11 to station B. Signals may also originate at station C in transmitters, such as 192, of channels which have two terminations at that station, such as channel 1. The signals originating at station C are also transmitted westwardly over cable 11 to station B. All of the signals arriving at station B from station C pass through amplifier 75 and relay 76 and are transmitted westwardly over line 10 to station A where they are printed by printers such as 16 and 17.

To facilitate adjustment of the relative angular positions of the cam shafts of timing device 240, as for instance in the initial adjustment or lining up of the system, the right-hand end (not shown) of shaft 260 is so mounted as to permit the left-hand bearing 310 of the shaft to be lowered and raised, and a cam 311 and cam latch 312 are provided for holding the shaft in its raised position. By releasing the latch and turning the cam 311, the gears of each of the gear trains 261, 262 and 263 may be disengaged. Similar means is provided, as shown, for facilitating adjustment of the relative angular positions of the cam shafts of each of the other timing devices, such as 240^b and 240^c.

Means will now be described for energizing the clutch control magnets such as 258, 258^b and 258^c in the manner mentioned above for causing engagement of the clutches such as 255, 255^b and 255^c substantially simultaneously.

At station A is a switch 315 having four movable contacts 316 to 319, of which contacts 316, 317 and 318 are transfer contacts, each movable between two stationary contact studs for connecting the first three transmitting segments 51 of channel 5 either to movable contacts of transmitter 19, as shown, or to negative battery. When the switch is in the position shown, the movable contact 319 is open; but when the contact is in its right-hand position it closes a gap in a circuit extending from negative battery through the latter contact, conductor 324, right-hand movable contact of a switch 325, clutch control magnet 258, middle movable contact of switch 325, conductor 326, a transmitter local segment 58, brush 59, and local ring 57, to ground.

At station B is a switch 330 which in the position shown closes a gap in the connection extending from the third of the active receiving segments of channel 5 through conductor 332, switch 330 and conductor 333 to the winding of storing relay 143. When the switch 330 is closed to the right, it disconnects the receiving segment just mentioned from relay 143 and connects the segment to ground through a circuit extending from that segment through conductor 332, switch 330, clutch control magnet 258^b and conductor 334. When magnet 258^b is energized by current sent through the latter path as described hereinafter, and releases clutch lever 331 from latch 257, the clutch lever operates switch 330 from its right-hand to its left-hand position, which is the position it should have when signals are to be transmitted through the rotary repeater comprising distributor 70 and storing relays 141 to 145.

At station C is a switch 335 which, in the position shown, closes at its left-hand movable contact, a circuit extending from the second active receiving segment 165 of channel 5, through conductor 336, left-hand movable contact of switch 335, and conductor 337, to the winding of the storing relay 163 corresponding to the receiving segment just mentioned. When switch 335 is operated to its right-hand position, its left-hand movable contact disconnects the receiving segment and storing relay winding just mentioned from each other, and connects that segment to ground through a circuit extending from that segment through conductor 336, left-hand movable contact of switch 335, conductor 338, and clutch control magnet 258^c.

With the system in the condition shown, if it is desired to energize the clutch control magnets such as 258, 258^b and 258^c for causing engagement of the clutches such as 255, 255^b and 255^c substantially simultaneously the switches 325, 330 and 335 should be operated from the positions shown to their right-hand positions. Thereafter, switch 315 may be operated from the position shown to its right-hand position. This operation of switch 315 should occur at a time after brush 52 has passed beyond the transmitting segment connected to contact 318 and has not reached the transmitting segment connected to contact 316 on its next passage over segments 51 from left to right in the drawing, and should also occur at a time after brush 59 has passed beyond the segment 58 to which conductor 326 is connected and has not reached that segment on its next passage over rings 57 and 58 from left to right in the drawing. Switch 315 having been thus operated, upon the next traverse of the brushes 52 and 59 over the segments connected to switch 315 and conductor 326 the brush 52 transmits to line 10 a pulse from negative battery (connected to the right-hand stationary contact studs of movable contacts 316, 317 and 318) as each of the segments connected to the switch 315 is traversed by that brush, and the brush 59 causes a pulse from negative battery (connected to contact 319) to energize clutch control magnet 258 over the circuit traced above for that magnet as the segment 58 connected to conductor 326 is traversed by that brush. The negative pulses transmitted to line 10 from the segments connected

to contacts 316, 317 and 318 pass over line 10 to relay 65 and common receiving ring 120 of distributor 70 at station B, and from ring 120 these impulses are transmitted by brush 123 to the corresponding ones of receiving segments 122 since the distributors of the system are operating in synchronism. The negative pulse thus transmitted from the third sending segment of channel 5 at station A and received by the third active receiving segment of channel 5 at station B energizes clutch control magnet 258^b over the circuit from that receiving segment through conductor 332, switch 330, and conductor 334 to ground, whereupon latch 257^b releases clutch lever 331, so that spring 256^b causes engagement of clutch 255^b and operation of switch 330 to its left-hand position.

The negative clutch control pulses transmitted from the first and second sending segments of channel 5 at station A and received by the first and second active receiving segment of channel 5 at station B energize storing relays 141 and 142 and are repeated to the first and second even numbered sending segments 127 and transmitted through brush 128 and ring 125 and eastwardly over cable 11 to station C where they are amplified by amplifier 89 and transmitted by relay 90 and brush 160 to the first and second even numbered receiving segments 165 of channel 5. The pulse thus received by the second of the even numbered segments 165 energizes clutch control magnet 258^c over the circuit extending from that segment through conductor 336, switch 335, magnet 258^c, and conductor 338, to ground, thereby releasing latch 257^c, whereupon spring 256^c causes engagement of clutch 255^c. The switch 335 may then be manually operated to its left-hand position so that it cannot interfere with signals to be subsequently transmitted through channel 5.

The clutch control pulse transmitted to the first even numbered segment 165 of channel 5 as described above, energizes the storing relay 163 connected thereto, and is transmitted from the storing relay to the first even numbered sending segment 167 of channel 5 and thence through brush 169 and ring 166 and eastwardly over cable 12 to the station (not shown) mentioned above as forming the east termination of the system. At the latter station, the re-received clutch control pulse energizes a clutch corresponding to clutches 255, 255^b and 255^c, in the manner in which clutches 255^b and 255^c are energized as described above.

When the clutch control impulses for the different stations have been generated at station A, the switch 315 may be operated to the position shown, so that the switch cannot interfere with signals to be subsequently transmitted by transmitter 19.

Since the impulses for operating the clutches at the different stations substantially simultaneously are all generated at station A, and the pulses sent from that station to the other stations require different times to reach the distributor segments on which the clutch control pulses are received at the stations east of station A, preferably the impulses for controlling the clutches at the different stations are originated at segments of distributor 30 which, as is shown in the drawing, the distributor brushes reach in the inverse order of succession of the stations along the cable circuit, starting from station A, in order to at least partly compensate for the lag of the line or cable. This lag, between stations A and C, may be of the order of three tenths of a second, for example.

The automatic switching of the system from the condition for transmission in one direction to the condition for transmission in the other direction starts at the same instant at both ends of the system. That is, the operation of the shafts such as 226 and 226^c starts at the same instant. The instant the end of the transmission period for one direction arrives, and regardless of whether the message being transmitted in that direction is completed, the transmitters are automatically locked up just after the last character is sent out from each one in turn. At the receiving end the printers are cut off just after they have each recived the last character sent from their respective transmitters. Thereafter in definitely timed steps the switching operations take place, transferring the cable from the sending network to the amplifier at one end and from the amplifier to the sending network at the other end and finally cutting in the transmitters and printers. Transmission is then resumed in the reverse direction, continuing the messages where they were stopped at the end of the preceding period for transmission in that direction, without any break in the printed records.

It may at times be desired to start the motors such as 227, 227^b, 227^c and $227^{c'}$ and stepping magnets such as 230, 230^b and 230^c manually, as for instance to observe whether the cam shafts 226, 226^b, 226^c and $226^{c'}$ stick or hesitate in operation or operate irregularly. Means is indicated at station C for accomplishing such starting of motors 227^c and $227^{c'}$ and magnets 230^c and $230^{c'}$, and it will be apparent from such indication how the corresponding motors and stepping magnets at the other stations may be similarly started.

At station C switches 360 and 361 are provided for manually starting motors 227^c and $227^{c'}$, respectively, and a key 362 may be depressed for closing the circuits of the magnets 230^c and $230^{c'}$ to start them stepping under control of segments 201 and 203. The circuit controlled by key 362 for magnet 230^c extends from negative battery to the magnet over the path traced above for operating the magnet,

and thence through the magnet conductor 278 and left-hand contact of key 362 to ground. The circuit controlled by key 362 for magnet 230$^{c'}$ extends from negative battery to the magnet over the path traced above for operating the magnet, and thence through the magnet, conductor 281 and the right-hand contact of switch 362 to ground. Magnet 230^{c} may be manually operated step by step when brushes 196 and 198 are at rest by alternately depressing and releasing a key 363, the circuit controlled by this key for the magnet extending from negative battery through the right-hand contact of the key, conductor 270, magnet 230^{c}, conductor 278 and left-hand contact of the key to ground. Similarly, magnet 230$^{c'}$ may be manually operated step by step when brushes 196 and 198 are at rest by alternately depressing and releasing a key 364, the circuit controlled by this key for the magnet extending from negative battery through the right-hand contact of the key, conductor 280, magnet 230$^{c'}$, conductor 281, and the left-hand contact of key 364 to ground.

The invention is disclosed herein by way of example, as applied to a specific submarine cable multiplex printing telegraph system having synchronously operating distributors at different stations and having switching means operable for conditioning the system to transmit in opposite directions alternately, the switching means being adapted for operation automatically and periodically under control of timing devices controlled by the distributors. A copending application of A. M. Curtis, Serial No. 119,537, filed June 30, 1926, discloses most of that system in more detail as regards certain features than does the instant application. The preferred form of the synchronizing means mentioned herein, for synchronizing the distributor brushes and correcting their positions, is claimed in a copending application of George A. Locke, Serial No. 123,328, filed July 19, 1926.

What is claimed is:

1. In a signaling system, synchronous distributors at respective stations, receiving devices individual to certain elements of the distributor at one station, an operating device different in character from said receiving devices, means for temporarily connecting said operating device to one of said elements, means at a distant station including the corresponding element of the distributor at said distant station for sending an impulse to operate said operating device, and means to disconnect said operating device from said element and restore the normal connection to its respective receiving device.

2. In a signaling system, synchronous distributors at respective stations, transmitting and receiving apparatus at said stations, connections for conditioning said apparatus for transmission in one direction only, means at said stations under the control of the respective distributors for reversing the direction of transmission, and means controlled at one of said stations for starting said reversing means substantially at the same moment, said last means comprising in series a source of potential, a distributor element at the controlling station, the simultaneously connected distributor element at the controlled station, and an electro-responsive device at the controlled station.

3. A system, according to claim 2, comprising an electro-responsive starting device at the controlling station operated through a distributor element other than said first mentioned element.

4. A system, according to claim 2, comprising a plurality of controlled stations each having a starting device, each of said starting devices being controlled over a separate series of distributor elements at its own and preceding stations.

5. A system, according to claim 2, in which is provided manually operated means for connecting the starting means to the distributor element, and means operated in response to the starting operation for disconnecting it.

6. The method of controlling electro-responsive means for controlling the connection of signal transmitting means and signal receiving means, alternately, to a signaling circuit extending between synchronous distributors, which comprises sending control current to said electro-responsive means over a path extending through said circuit and extending through one of said distributors.

7. A multiplex signaling circuit, synchronous distributors included in said circuit, means operable for changing said circuit from a condition for transmitting signals in one direction to a condition for transmitting signals in the opposite directions, and vice versa, periodically at predetermined time intervals, electro-responsive means for controlling the starting of the first mentioned means, and a control circuit for said electro-responsive means extending through said distributors and extending through a part of said signaling circuit included between said distributors.

8. The method of claim 6 which comprises amplifying the energy of said control current in the passage of said current through said circuit.

9. The combination with a transmission line of signal transmitting means at each terminal, signal receiving means at each terminal, signal repeating means between said terminals, means operable to vary the connection of said line at predetermined time intervals from said transmitting means to said receiving means and vice versa, means operable to condition said repeating means for repeating in opposite directions in said line at predetermined time intervals equal to said first mentioned intervals, one direction only

at a time, electro-responsive means operable for starting said connection varying and repeater condition means, and means for transmitting current over said line, from one of said terminals to said other terminal and to said repeater, for controlling said starting means.

10. A signaling system comprising two stations and a station intermediate said two stations, a signaling line interconnecting all of said stations, means at each of said stations operable for conditioning that station for transmission alternately in opposite directions in the system at predetermined time intervals, electro-responsive means operable for starting said first mentioned means, and means for transmitting current over said line, from one of said stations to said other two stations, for controlling said starting means.

In witness whereof, we hereunto subscribe our names this 25th day of June, A. D. 1926.

GEORGE A. LOCKE.
HAKON H. HAGLUND.