Nov. 17, 1931. W. A. KNOOP 1,832,308

INTERPOLATING SYSTEM

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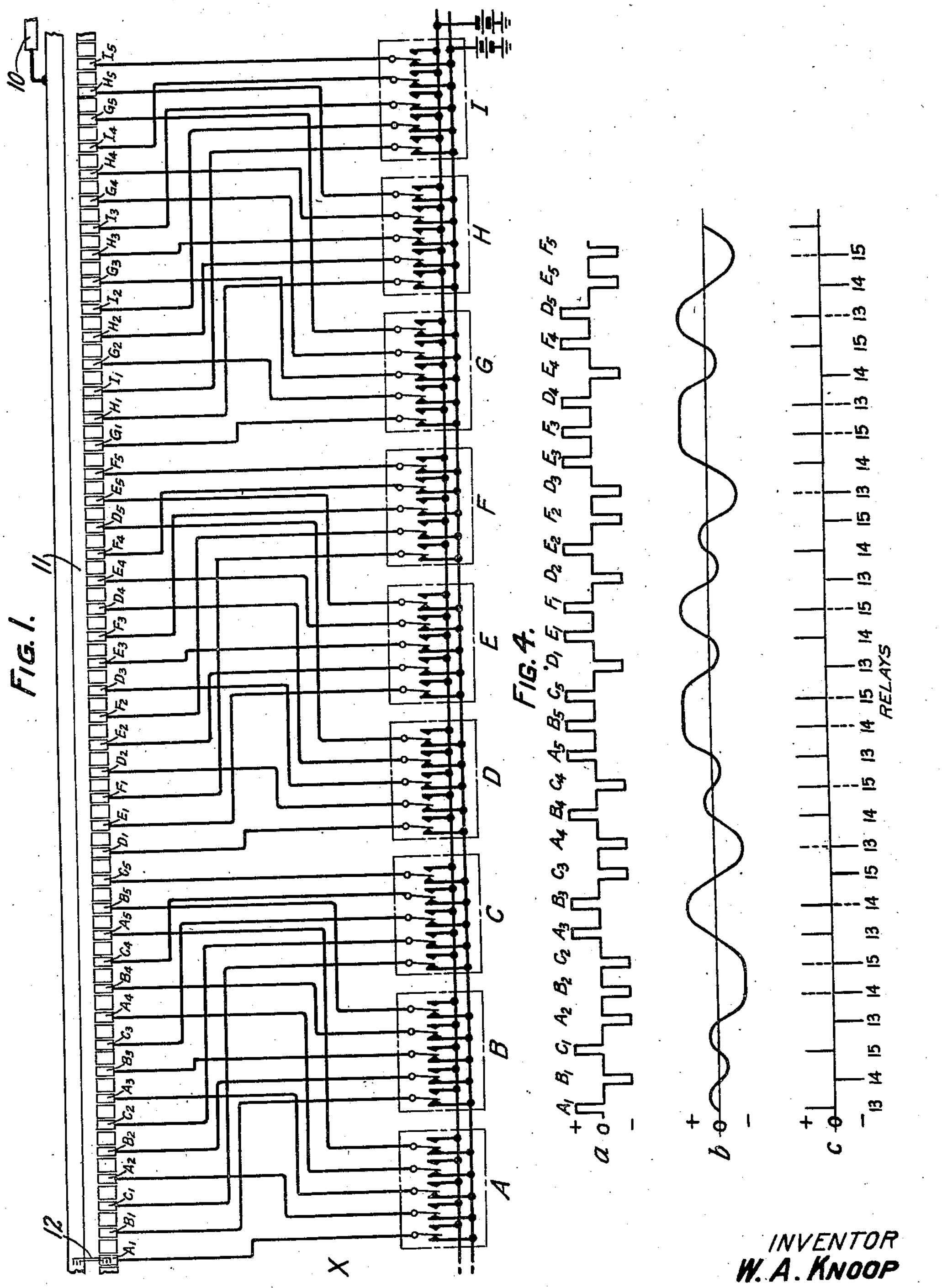

FIG. 1.

FIG. 4.

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FIG. 2.

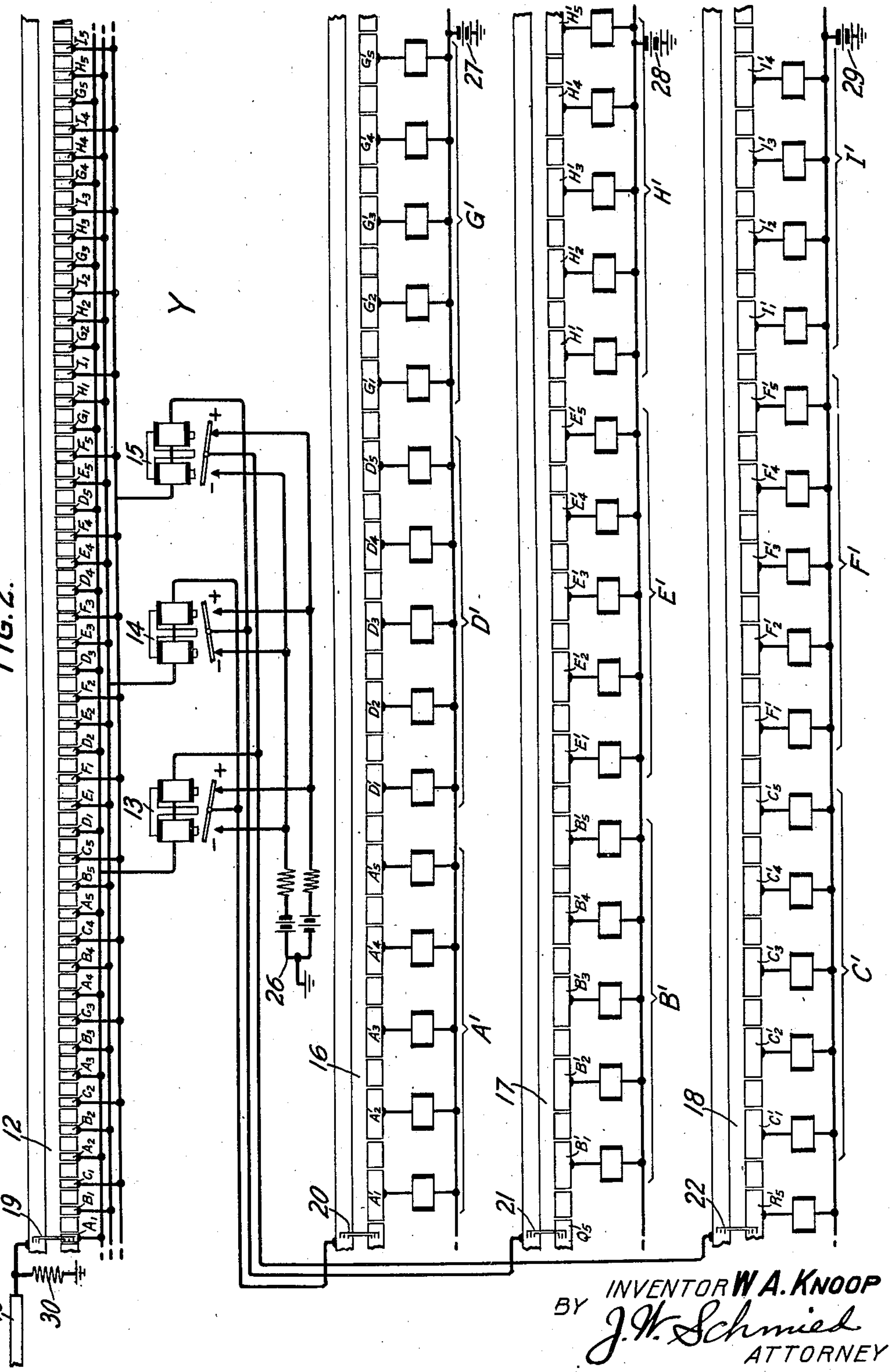

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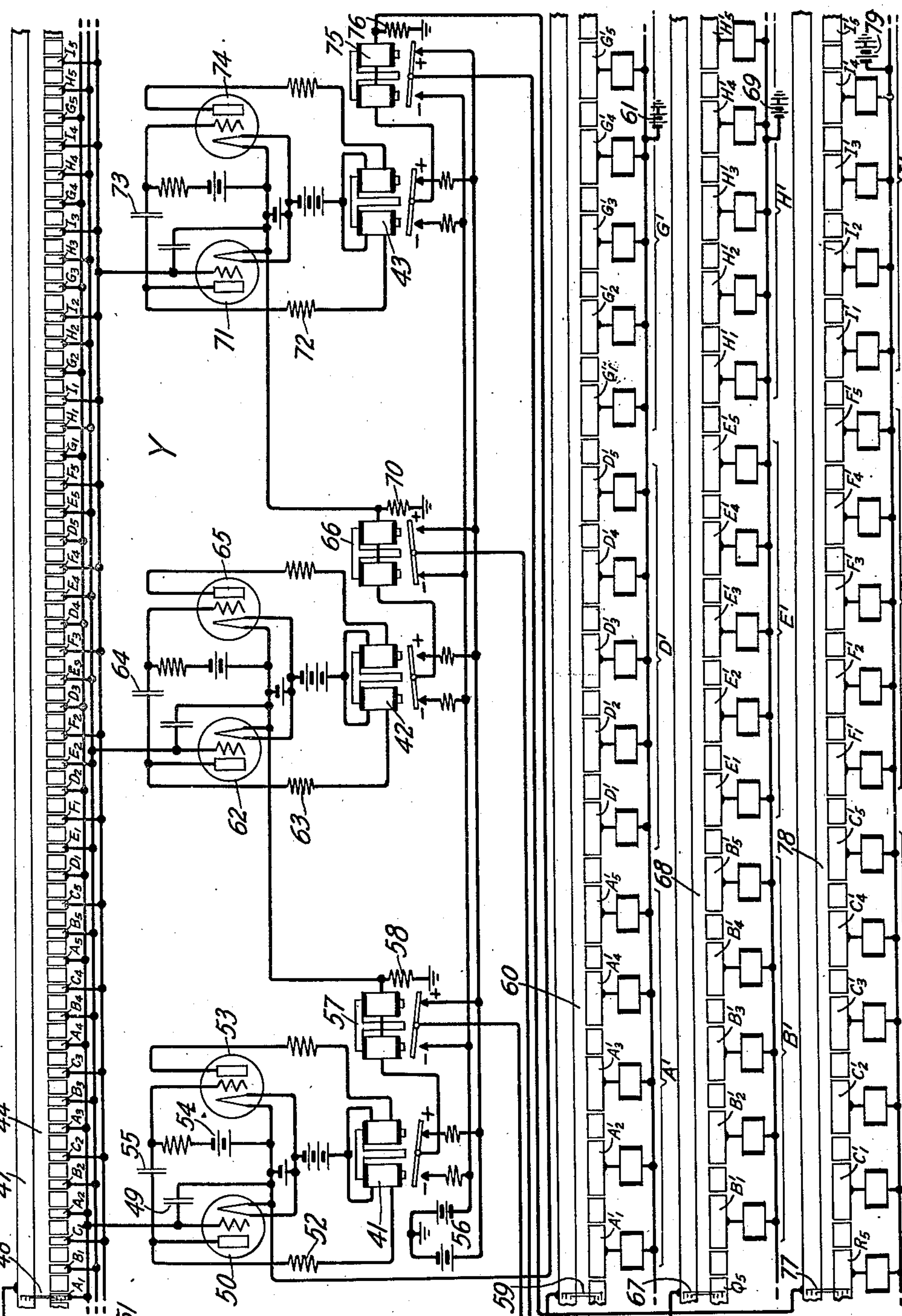
FIG. 3.



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INTERPOLATING SYSTEM

Application filed December 31, 1928. Serial No. 329,439.

This invention relates to synchronous telegraph systems, and particularly to interpolating receiving systems for use with high speed telegraph conductors such as loaded submarine cables.

Objects of the invention are to simplify and to increase the effectiveness of interpolating receiving systems.

Another object is to repeat signal impulses from a plurality of low speed lines into a single high speed line, and, after transmission thereover to interpolate the single impulses which have been lost during transmission and retransmit all impulses into a plurality of lines corresponding to those at the originating end.

In high speed signaling transmission systems short signal impulses are attenuated because of the characteristics of the transmission line, and must be rebuilt at the receiving end or the relaying point. Heretofore receiving systems for this purpose have been commonly termed vibrating relay systems. This expresion is somewhat misdescriptive of the system of this invention because short impulses are rebuilt without necesarily vibrating any relays and therefore in this specification the expression interpolating receiving system will be used to define a system which restores or interpolates short signal impulses which have been attenuated to such an extent that they are incapable of controlling a receiving relay or a relay for retransmitting the impulses into the next line section. It has been the practice heretofore to interpolate at the receiving end of a telegraph circuit missing signal impulses of unit length which has been practically completely attenuated during transmission because of their high frequency. The applicant's copending application, Serial No. 253,239, filed February 10, 1928, disclosed an interpolating system in which a pair of receiving relays have line windings arranged to be energized by the incoming signals, and local or interpolating windings arranged to be energized under the control of the contacts of both relays. When no signals are being received the local or interpolating windings are energized to hold the relay armatures against contacts of opposite polarity whereby unit impulses of alternate positive and negative polarity are generated as the brushes on a rotary distributor make contact with segments alternately connected to each relay. When signal impulses of greater than unit length are received the current in the line windings increases, thereby moving the relay armatures against contacts of like polarity to generate a series of impulses of the polarity corresponding to the received impulse of greater than unit length.

The system of the present invention differs from those previously known, notably that disclosed in applicant's copending application, in that the separate interpolating and line windings have been eliminated, the line voltage and the interpolated voltage being superimposed on the same windings of each relay. Furthermore, a system is disclosed in which a plurality of interpolating receiving relays receive signals from a plurality of channels on a high speed telegraph conductor or cable and retransmit them directly into a plurality of low speed lines.

In the drawings, Figs. 1 and 2 show a schematic circuit in which any odd number of receiving relays may be used, three being shown for the purpose of illustration;

Fig. 3 is a modification of Fig. 2, wherein vacuum tube storing and impulse lengthening arrangements are used in conjunction with an odd number of relays;

Fig. 4 shows curves representing the operation of the circuit arrangements shown in Figs. 2 and 3.

Description of the circuit of Figs. 1 and 2.—Arranging Fig. 2 at the right of Fig. 1, a system is shown wherein nine transmitters, A, B, C, D, etc. at station X are respectively connected in rotation by cable 10 to a corresponding number of printers designated A′, B′, C′, D′, etc. at station Y. The cable is designed for high speed transmission and in order that low speed lines may be connected thereto at the sending end, the transmitters in Fig. 1 may be replaced by a plurality of relays (not shown) operably connected to low speed lines. This may be accomplished in one way, which is not shown in the drawings, by having the low speed lines each terminate in a rotary distributor, the receiving segments of which may be connected to a receiving relay. Each receiving relay would reproduce the signals received over its associated distributor and these reproduced signals would in turn be impressed on the high speed cable through a sending distributor of a type hereinafter described. In such an arrangement the segments of the receiving distributors would be longer than those of the sending distributor, for instance, should there be three receiving distributors the receiving segments would be approximately three times the length of the sending segments, the brushes of the receiving distributors would with respect to each other be offset in a progressive order the distance of one sending segment so that the receiving relays would be successively operated and released in the order of the relative brush positions, and the brush of the sending distributor would be aligned with the receiving brush in last position. In this way one receiving relay would replace each transmitter.

In order to repeat the high speed signals incoming at station Y over a plurality of low speed lines or, if station Y is the terminating point, to slow-acting selector magnets in the printers, the signals from each transmitter are interspersed on the cable with those from the other transmitters. This is because slow-acting repeating relays or the selector magnets will not respond to the impulses as received from the cable but will respond when these impulses are lengthened in the course of reproducing them to the repeating relays or printers by the receiving relays. As the operation of interspersing the transmitted impulses depends upon the reception of the impulses from the different transmitters successively the transmitters are connected in groups to the sending distributor 11 at station X, the transmitters in each group corresponding in number to the receiving relays at station Y. The transmitters of each group are so connected to the distributor 11 that one impulse from each transmitter in a group is sent successively and this operation is repeated until all five impulses of each transmitter in the group are sent. In other words, an impulse from transmitter A is followed by an impulse from transmitter B, and then by an impulse from transmitter C, this operation being repeated with the other impulses from each of the transmitters A, B and C, until all five impulses from each of the transmitters are sent. Transmitters D, E, F, in a group, and G, H, I, in another group are similarly connected to the sending distributor 11 and these are operated in the same manner as that described above for the group of transmitters A, B and C.

The impulses from transmitters A, B and C are received at station Y, by receiving distributor 12 as shown in Fig. 2 and successive impulses impressed in succession on three receiving relays 13, 14 and 15, respectively. Similarly, the impulses of each of the three transmitters of the other two groups are also impressed on these relays. The receiving distributor at station Y has alternate live and dead segments so as to connect the receiving relays to the line for that portion of time when the center of an impulse is due to arrive. In high speed operation the signals of unit impulse length are not present in the received signals and any impulse that operates the receiving relay must be one forming a part of a signal of at least two units in length. These relays are of the polarized type and each is biased momentarily through distributor 12 by and in the opposite direction to the relay preceding it.

The armatures of relays 13, 14 and 15 are respectively connected to three printer ring sets 16, 17 and 18, each of which comprises a continuous and a segmented ring. The segmented rings each consist of ten alternate live and dead segments for each transmitter so that for the nine transmitters, with the received signals split three ways as shown, each segmented printer ring has thirty alternate live and dead segments. The printer rings are concentrically arranged with the receiving ring set 12. one brush arm being provided with brushes for the four ring sets disposed in radial alignment. The live segments of the printer ring sets are approximately twice the length of the dead segments so as to permit the use of slow-acting printer magnets, or repeating devices should further transmission be desired. In practice these live and dead segments are made of equal lengths in order that a slight mal-adjustment of the brushes may be permitted without causing error. The live segments A'_1, A'_2, A'_3, A'_4 and A'_5 are respectively connected to the magnets of printer A', the live segments B'_1, B'_2, B'_3, B'_4 and B'_5 are connected to the magnets of printer B', and so on for the remaining live segments, each group of five being connected to the magnets of a printer as shown. In order to have the proper sequence of operation for the printers the segments of each of the three printer ring sets 16, 17 and 18 are so positioned with respect to the live segments of receiving ring set 12 that when a receiving brush 19 on ring set 12 is passing through the center of a receiving or live segment the brush of the printer ring set containing the corresponding live segment, is in the center of the dead segment immediately at the left hand side of such corresponding live segment. In other words, should brush 19 be passing the center of segment A_3 of ring set 12, brush 20 would be in the center of the dead segment to the left of segment A'_3. Therefore, in accordance with the arrangement of the live segments of ring set 12 and the corresponding segments in ring sets 16, 17 and 18, printers A', B', C', D', etc. will be operated in sequence.

In order to interpolate impulses at station Y to replace those of unit length which are lost or greatly attenuated during transmission, currents of alternate positive and negative polarities are generated from a local source of potential 26 as brushes 19, 20, 21 and 22 rotate over their respective ring sets, providing, of course, that no signal impulses of two or more units length are received in the interim from the cable. The relays 13, 14 and 15 respond in rotation as brush 19 rotates over the live segments of ring set 12, and thereby assume alternately opposite positions which relationship is maintained regardless of what odd number of relays are employed. During the rotation of the brush 19, the relays 13 continue to vibrate to preserve the relationship. This relationship causes to be transmitted from battery 26, as brushes 20, 21 and 22 rotate over the printer ring sets 16, 17 and 18 respectively, long impulses of alternately opposite polarities to the printers A', B' and C', an impulse to printer A' being followed by an impulse to printer B' and then by an impulse to printer C'. These impulses to printers A', B' and C' are continued, should no long impulses be received from the cable, until all five impulses are received by each printer, at which time the impulses will then be directed to the printers D', E', and F', and so on. In the event that a long impulse is received from the cable, the cable current will be superimposed on the biasing current in any one or all of the relays 13, 14 and 15 and will be of sufficient strength to operate the relay, or hold it operated should the armature thereof be in the desired position regardless of the biasing current. The biasing current is adjusted to a suitably small valve as compared with the cable current of a long impulse.

The practice of reversing polarity between certain channels or within channels, in order to produce a more perfect balance of polarities on a submarine cable on a multiplex signaling system, has not been shown. It may be accomplished by reversing the battery leads of the transmitters shown in Fig. 1, at any point between or within the transmitters and also by connecting each of the battery leads of the three printer sets, shown in Fig. 2, at corresponding points to opposite poles of a battery having a mid-tap to ground.

Operation of the circuit arrangement of Figures 1 and 2.—The unit impulses of alternate positive and negative polarity transmitted from the distant station X are greatly attenuated during transmission and consequently do not operate receiving relays 13, 14 and 15, but when the signals made up of impulses of two or more units length of like polarity, are received, the current thereof rises to an amplitude sufficient to operate or hold operated the relays arranged to receive the second and subsequent unit parts of the signal. It will be noted that relays 13, 14 and 15 are in alternate positive and negative positions and this relationship will be retained as long as the signals of unit length are on the line, which means that relays 13, 14 and 15 will furnish signals of alternate positive and negative polarities to operate the printer magnets shown connected to the segments of ring sets 16, 17 and 18 in the same manner as would be effected by the signals of unit length, if such were received without attenuation. This mode of operation resides in the arrangement of relay circuits whereby the operation of one relay depends upon the position of the one preceding it when no signal impulses of value sufficient to hold the relays are being received.

As an illustration, let is be assumed that there are no effective impulses being received from the cable and relay 13 is in the position shown at the time brush 19 is passing over segment A_1 of ring set 12. When brush 20 reaches segment A'_1 the circuit extending from the positive pole of battery 26 over the right hand or positive contact and armature of relay 13 through the first magnet of printer A_1, to the negative pole of battery 27 is completed and the magnet of printer A'_1 operates.

When brush 19 reaches segment B_1 the circuit is closed extending from the positive pole of battery 26 through the right hand contact and armature of relay 13, and the windings of relay 14, segment B_1, brush 19, resistance 30 to ground. A current flows from battery 26 through the windings of relay 14, and this current is of sufficient strength and in such direction as to operate relay 14 to its left hand or negative contact. When brush 21 reaches segment B'_1 the operation of relay 14 to its negative contact closes a circuit extending from the negative pole of battery 26, left hand contact and armature of relay 14, through the winding of the first magnet of printer B' to the negative pole of battery 28. No current flows in this circuit, and therefore the first magnet of printer B' does not operate. When brush 19 reaches segment C_1, current flows from negative pole of battery 26 through the windings of relay 15 over segment C_1 and brush 19 to ground at resistance 30, causing relay 15 to operate to its right hand or positive contact. Relay 15 in operating connects the positive pole of battery 26 to brush 22 which upon reaching segment C'_1

completes the circuit extending through the winding of the first magnet of printer C′ to the negative pole of battery 29. The batteries in this circuit aid each other and the magnet therefore operates.

When brush 19 reaches segment A_2 the circuit is closed from ground at resistance 30, brush 19 and segment A_2, through the windings of relay 13, right hand contact of relay 15 to the positive pole of battery 26. The current in this circuit flows through relay 13 in such a direction as to operate the relay to its left hand or negative contact. As brush 19 rotates over the remaining live segments of ring set 12 the receiving relays will continue to reverse their positions so that impulses of alternate positive and negative polarities will be generated when no long impulses are received from the cable, the magnets of printers A_1, B_1, C_1, etc. responding when, and only when, impulses of positive polarity are generated.

Referring to Fig. 4, a clear understanding of the method of interpolating impulses of unit length in a message whereof the transmitted unit impulses have been lost in transmission, may be had. Let curve *a* represent the signal wave as it is transmitted from station X, curve *b* the same wave as it is received at station Y with the impulses of unit length greatly attenuated and curve *c* indicates the operation of the receiving relays. In curve *c* the full vertical lines indicate the polarities of the signals regenerated at station Y, in response to either the impulses received from the line or the interpolated impulses, to operate the relays and the dotted vertical lines indicate the polarity of the interpolated impulses which tend to operate the relays at the time the relays are under the control of incoming line signals. In curve *a* the first impulse is of unit length and of positive polarity but by the time it passes from station X to station Y it is greatly attenuated as shown in curve *b*. This impulse flows through the windings of relay 13 when brush 19 passes over segment A_1, but it is ineffective to operate the relay. As hereinbefore assumed, the armature of relay 13 is in engagement with its right hand or positive contact, indicated by the first vertical line in curve *c*, and when brush 20 reaches segment A'_1 the first magnet of printer A_1 operates. As brush 19 passes on to segment B_1 an operating current flows from battery 26 through windings of relay 14 to ground through resistance 30. This current is in such a direction as to tend to operate relay 14 to its negative position as shown, and inasmuch as the incoming signal impulse simultaneously received by segment B_1 is of unit length and consequently low in amplitude the current from battery 26 predominates and operates the relay to its negative position, as shown by the second full vertical line in curve *c*. When brush 21 reaches segment B'_1 of ring set 17 negative battery 26 is connected to negative battery 28 through the first magnet of printer B_1, but the magnet does not operate because of opposing polarities.

When brush 19 reaches segment C_1 the current from battery 26 flows through the windings of relay 15 in such a direction as to tend to operate the relay to its positive position, as shown by the third full vertical line of curve *c*. Inasmuch as the third impulse designated in curve *b* as positive is of unit length the current from battery 26 not only tends to operate but does operate relay 15 to its positive contact. As the brushes continue to rotate, brush 22 reaches segment C'_1 of ring set 18 and connects positive battery 26 over the right hand contact of relay 15 and through the first magnets of printer C′, to negative battery 29, thereby setting the magnet in operated position. When brush 19 reaches segment A_2 the circuit extending from ground, resistance 30, brush 19, segment A_2, winding of relay 13, right hand contact and armature of relay 15 to positive battery 26, is closed and the current through relay 13 is in such a direction as to operate the relay to its negative position as indicated by the fourth vertical line in curve *c*. As brush 20 reaches segment A'_2 the negative pole of battery 26 is connected through the winding of the second magnet of printer A′ to the negative pole of battery 27, but due to opposing poles being interconnected the magnet does not operate. This operation is repeated as long as no effective signal impulses of two or more units length are received and the interpolating impulses are therefore of alternate positive and negative polarities.

However, it will be noted that the fourth impulse in curve *b* is the beginning of a long impulse of three units length and consequently the line current of the long impulse rises to an amplitude sufficient to predominate over the current from battery 26 in controlling the receiving relays connected to the segments over which brush 19 is passing at the time. Accordingly, as brush 19 reaches segment B_2, the second unit of the long negative signal is being received from the line and the strength of this impulse is sufficient to hold relay 14 in its negative position, although at the time the interpolating current from battery 26 was flowing in the opposite direction through the windings of relay 14, so as to tend to operate the relay to its positive position. The polarities of these opposing currents are indicated in curve *c* by the fifth vertical line, the solid portion representing that of the line current, and the dotted portion representing that of the interpolating current. When brush 21 reaches segment B'_2 the negative poles of battery 26 and 28 are interconnected through the winding of the second magnet of printer B′ and the magnet remains normal.

When brush 19 reaches segment C_2 the current from battery 26 flows through the windings of relay 15 in such direction as to ordinarily cause the relay to remain in its positive position but inasmuch as the strong negative current on the line is flowing at the same time in the opposite direction through the relay windings the relay armature moves over to its negative contact. In curve *c* the polarities of the currents flowing through the windings of relay 15 are represented by the sixth vertical line, the dotted portion representing the tendency of the interpolating current and the solid line representing the effective line current voltage. As brush 22 reaches segment C'_2 the negative pole of battery 26 is connected to the negative pole of battery 29 and therefore the second magnet of printer C′ does not operate.

At the end of the long impulse of three units length the line current reverses to form a long signal of positive polarity and as brush 19 reaches segment A_3 the interpolating current from battery 26 becomes effective to move relay 13 to its positive contact because the line current has dropped off to zero value. The seventh vertical line in curve *c* represents the positive polarity of a regenerated or interpolating current, overcoming the line current voltage which has now reached a negligible value. The remaining portions of curves *b* and *c* will be readily understood from the foregoing.

Description of circuit of Figure 3.—Fig. 3 shows a modification of the receiving equipment shown in Fig. 2, wherein a pair of vacuum tubes are employed with each receiving relay for storing the signal impulses and for upsetting the normal balance of space current values in any one pair of vacuum tubes to control the operation of its associated relay. In this figure the grouping of transmitters and printers is the same as that shown in Figs. 1 and 2, the only difference in the equipment being, in addition to the vacuum tubes, the provision of a printer relay for each group of printers and the differential character of the receiving relays. As in Fig. 2, there is an odd number of receiving relays, such as those designated 41, 42 and 43 and these also are assumed to be in alternately positive and negative positions so that when there are no signals being received at station Y the impulses which are interpolated will be of alternate positive and negative polarity.

When the first part of a signal of two or more units length, say, of positive polarity, is received over segment A_1 of the receiving ring set 44, a voltage drop is produced across resistance 45. This voltage drop is applied through condenser 46 to the signal common ring 47, brush 48 and segment A_1 to the condenser 49 and grid of vacuum tube 50. Battery 51 is also applied over the ring set 44 to the grid of tube 50 to give it a normal negative bias. As the brush 48 engages segment A_1 the first part of the signal causes a positive charge to be stored up on condenser 49 and this charge prolongs the positive potential simultaneously impressed on the grid by the signal itself. Consequently, the space current in tube 50 and the left hand winding of relay 41 is increased. The second vacuum tube 53 of the first pair has its grid normally biased negatively with respect to its filament by a battery 54 and as the space current of tube 50 flows through a resistance 52 a voltage drop is produced across the resistance in such a direction that a positive potential is impressed on condenser 55 to make the grid of tube 53 more negative, thereby causing a decrease in the space current in tube 53 and the right hand winding of relay 41. The predominance of current in the left hand winding of relay 41 holds the armature of the relay against its right hand or positive contact. The interengagement of the armature and right hand contact of relay 41 allows a positive current to flow from battery 56 through the windings of printer relay 57 and resistance 58 to ground. Relay 57 moves its armature to its right hand or positive contact and as brush 59 reaches segment A'_1 of printer ring set 60 a positive current flows from battery 56, right hand contact of relay 57, brush 59, segment A'_1 through the winding of the first magnet of printer A_1 to the negative pole of battery 61, thereby causing the magnet to operate.

The positive current flowing through relay 57 produces a voltage drop across resistance 58 in such a direction as to make the filament of tube 62 of the second pair of vacuum tubes more positive with respect to the grid and should no signal be received when brush 48 reaches segment B_1 the effect of the voltage drop across resistance 58 would cause a decrease in the space current in tube 62 and the left hand winding of relay 42. Included in the plate circuit of tube 62 is resistance 63 and the voltage drop across this resistance would impress a negative charge on condenser 64 and this in turn would make the grid of tube 65 of the second pair positive with respect to its associated filament. Consequently, the space current in tube 65 and the right hand winding of relay 42 is increased. This would result in relay 42 holding its armature at its left hand or negative contact as shown. But as it was assumed above that the incoming signal was of two or more units length the voltage drop across resistance 58 is overcome by the signal voltage because the second unit of the positive signal is being simultaneously received over segments B_1 and the resulting action of the tubes 62 and 65 is the same as that described above for tubes 50 and 53. Therefore, the action of tubes 62 and 65 in response to the second part of the long positive signal causes relay 42 and printer relay 66 to move their respective armatures to their right hand or positive contacts. When brush 67 reaches segment B′ of ring set 68 a positive current flows from battery 56 through the winding of the first magnet of printer B′ to the negative pole of battery 69 and the magnet operates.

In the circuit extending through the windings of relay 66 there is included a resistance 70 across which a voltage drop is produced when the positive current from battery 56 operates printer relay 66. This voltage drop is applied to the filament of tube 71 of the third pair of tubes and is in such a direction as to make the filament more positive with respect to its associated grid when brush 48 makes contact with segment C_1. Assuming that the next signal transmitted from a distant station is of negative polarity and of unit length, no effective impulse will be received at station Y as brush 48 reaches the corresponding segment C_1. The regenerated positive voltage applied to the filament of tube 71 will cause a decrease in the normal space current flowing through the left hand winding of relay 43. Included in the plate circuit of tube 71 is resistance 72 and therefore the voltage drop across resistance 72 by the decrease of space current applies a negative charge on condenser 73. This charge makes the grid of tube 74 of the third pair more positive with respect to the filament and the space current flowing through the right hand winding of relay 43 is therefore increased. This unbalance of the space currents in relay 43 causes the relay armature to engage its left hand or negative contact to close the circuit extending through the windings of printer relay 75, resistance 76 to ground. Relay 75 operates and connects the negative pole of battery 56 when brush 77 reaches segment C'_1 of ring set 78, to the negative pole of battery 79. The circuit extends through the winding of the first magnet of printer C′ but this magnet does not operate at this time because batteries 56 and 79 are opposing. The voltage drop produced across resistance 76 applies negative potential to the filament of tube 50 and if the next transmitted impulse is of positive polarity and of unit length no effective signal will be received from the cable. Therefore the negative potential set up on the filament of tube 50 by the resistance 76 causes the space current in tube 50 to be increased and the corresponding current in tube 53 to be decreased thereby operating relays 41 and 57 to their positive positions. The positive pole of battery 56 is therefore connected through the second magnet of printer A′ to the negative pole of battery 61 when brush 59 reaches segment A'_2, and the second magnet of printer A′ is operated.

This operation is repeated until the printers A′, B′ and C′ have been respectively set in the positions corresponding to the three characters transmitted by transmitters A, B and C shown in Fig. 1. Any number of groups of printers such as D′, E′ and F′, and G′, H′ and I′ may be added and these operated in sequence by relays 57, 66 and 75. It will be noted that when no effective signals are being received that the regenerating resistances 58, 70 and 76 produce a biasing voltage for the tube following and thereby cause unit impulses of alternate positive and negative polarity to be produced. In this way the impulses of unit length which are lost in transmission are inserted at their proper positions by employing pairs of vacuum tubes to control the operation of a receiving relay, the number of pairs being determined by the number of printers desired.

Operation of the circuit of Figure 3.—The operation of this circuit shown in Fig. 3 is substantially the same as that described above for Fig. 2 taken in conjunction with Fig. 4.

In addition to embodiments of the invention comprising odd numbers of receiving relays there are modifications including even numbers of receiving relays. Some of these are disclosed and claimed specifically in a subsidiary patent application Serial No. 432,288, filed March 1, 1930.

What is claimed is:

1. A synchronous interpolating system, characterized in this that it comprises a plurality of relays, means whereby said relays are successively connected in rotation to be capable of being affected by the received impulses and to be capable of being simultaneously affected by the preceding relay and in the opposite sense to the impulse operating the preceding relay, the impulses simultaneously affecting each relay being effective upon common relay windings.

2. A synchronous interpolating system having a transmission line, characterized in this that it comprises a plurality of relays, means whereby said relays are successively connected to said line in rotation to be capable of being affected by the signals received from said line and to be capable of being simultaneously affected by the preceding relay and in the opposite sense to the signal operating the preceding relay, each of said relays being provided with windings upon which the signals from said line are superimposed on the signals from the preceding relay, and means for registering the operation of said relays in response to either the signals received from said line or to the signals received from the preceding relay, said relays being operated in response to the stronger of the two signals simultaneously received.

3. A synchronous interpolating system

having a transmission line, characterized in this, that it comprises a plurality of receiving relays, means whereby said relays are successively connected to said line, to be capable of being affected over common windings by the impulses received from said line and by the impulses simultaneously received from the preceding relay, and in the opposite sense to the impulse operating the preceding relay, and a plurality of relays respectively associated with said receiving relays and arranged to be operated by said receiving relays to produce a record consisting of the impulses received from said line and the impulses received from the preceding relay, said relays being operated in response to the stronger of the two signals simultaneously received.

4. In a synchronous telegraph system, an interpolating receiving circuit, characterized in this, that it comprises a plurality of relays respectively connected to a plurality of printer rings on a receiving distributor and each having windings for receiving incoming signal impulses, and a plurality of means respectively associated with said relays for impressing on each of said windings impulses received from the preceding relay to generate unit impulses of alternate positive and negative polarity when the incoming signal impulses are ineffective to control and operate said relays.

5. In a synchronous telegraph system comprising a line, a receiving distributor connected to said line and an interpolating circuit, characterized in this, that a plurality of relays having windings for receiving incoming signal impulses, respectively connect a plurality of printer rings to a receiving ring on said distributor and a plurality of elements respectively associated with said relays for cooperating with a plurality of segments on said receiving rings to regenerate alternate positive and negative impulses and means for impressing on each of said windings concurrently with the signal impulses the regenerated alternate positive and negative impulses for interpolating said impulses in their proper places between the impulses received from said line whenever said relays fail to respond to the line impulses.

6. In a synchronous telegraph system comprising a line, a rotary distributor connected to said line and an interpolating circuit, characterized in this, that a plurality of relays having windings for receiving incoming signal impulses, a corresponding number of circuits each including the armature and contacts of one of said relays, the windings of another of said relays and a resistance element for transmitting over said windings unit impulses of alternate positive and negative polarity, and a plurality of groups of receiving segments on said distributor for transmitting impulses from said line over said windings concurrently with said unit impulses, the unit impulses being of sufficient strength to operate said relays whenever said relays receive insufficient line current to actuate them.

7. In a telegraph receiving system, a source of line signal impulses, a plurality of receiving relays, and synchronous distributing means for connecting to a winding of each relay in rotation, in series connection, said source of line signal impulses, a local source of current and contacts of the preceding relay.

8. In a synchronous telegraph receiving system, a plurality of repeating devices adapted to supply positive and negative impulses, synchronous switching means for distributing received signal impulses to said repeating devices in rotation and for concurrently superimposing on the windings of each repeating device a current impulse from the preceding device of such polarity as to tend to operate said device to a position opposite that of the preceding device, and means for utilizing impulses from the first mentioned devices.

9. In a synchronous multiplex telegraph system, a sending station and a receiving station, a transmission circuit interconnecting said stations, a plurality of transmitters at the sending station, means for applying signal impulses from said pluralitv of transmitters to said circuit in rotation, the impulses of one transmitter interleaved with those of the other transmitters, a plurality of receiving relays at the receiving station, and means at said receiving station for applying impulses to said receiving relays in rotation, whereby all impulses from any one transmitter may be received on one only of said relays, and means comprising said relays for interpolating at the receiving station signal impulses of alternate positive and negative polarity to replace those which have been appreciably attenuated during transmission.

10. In a synchronous telegraph receiving system, a local source of potential, a plurality of relays each having a double winding and a movable armature operable between two contacts connected to opposite poles of said source, synchronous switching means for distributing received signal impulses to the double winding of each relay in rotation, a plurality of circuits each including one of said armatures and a resistance element, each of said circuits being effective to superimpose an impulse from the armature of the preceding relay concurrently with a received signal impulse, on both windings of each of said relays, the former impulses being of such polarity as to tend to operate the armature of such relay to a position opposite that of the armature of the preceding relay, signal recording means, and other synchronous switching means for connecting the armatures of

the relays to said recording means in rotation.

11. In a synchronous telegraph system, comprising a plurality of transmitters arranged in groups, a line connected to said groups of transmitters, a rotary distributor for receiving the impulses from said groups of transmitters, the impulses of each transmitter of a group being interleaved with the impulses of the other transmitters of the group, a relay for receiving the impulses of a transmitter in each group, said relays being responsive to adjacent received impulses of one polarity and non-responsive to adjacent received impulses of opposite polarity, a plurality of printer rings on said distributor corresponding in number to the transmitters in a group, a plurality of circuits each comprising a local source of current, the armature and contacts of one relay and the windings of the next succeeding relay capable of operating said relays in rotation to alternate positive and negative positions when said relays fail to respond to the received impulses, characterized in this that the received impulses and impulses from said local source are simultaneously applied to common windings on said relays.

12. A synchronous telegraph system comprising a transmission line, a plurality of impulse transmitters for said line, a transmitting distributor, and a receiving distributor, at the receiving end of said line having a plurality of receiving rings respectively arranged to receive impulses from said transmitters.

13. A synchronous telegraph system comprising a relatively high speed transmission line, a plurality of low speed transmitting devices arranged in groups, means for interleaving the impulses of one transmitting device with those of the other transmitting devices in the same group for transmission over said line, a relay for receiving from said line the impulses of each transmitting device, a source of potential at the receiving terminal of said line arranged to be impressed on each of said relays concurrently with said line impulses through common windings on said relays and capable of producing impulses of alternate positive and negative polarity when the line impulses are ineffective to operate the relays, means for interpolating said impulses of alternate positive and negative polarities in the received signals to replace impulses lost during transmission over said line, and slow acting devices for combining and registering the received and interpolated impulses of each transmitting device separately.

14. In a synchronous telegraph system, a transmission line, a plurality of transmitters arranged in groups, means for interleaving the impulses of one transmitter with those of the other transmitters in the same group for transmission over said line, a plurality of pairs of three electrode vacuum tubes, each pair arranged to receive all the impulses from one of the transmitters in a group, differential relays each having its windings respectively connected in the plate circuits of one pair of vacuum tubes, said relays being responsive to a train of received impulses of one polarity, a movable armature and a pair of contacts on each of said relays, a source of potential having its opposite poles respectively connected to said contacts, printer relays having windings respectively connected to each of said armatures, and means associated with each of said printer relays for operating the next succeeeding differential relay, when transmitted impulses are of alternate positive and negative polarities.

15. In a signaling system, a line, a plurality of three-electrode vacuum tubes associated with said line, means for applying signal voltages to the grids of said tubes in rotation, a plurality of relays connected to said tubes, a local source of potential, and means for applying to each of said grids in rotation a voltage from said local source simultaneously with a signal voltage from said line, the voltage from the local source being effective to operate the relay only when no signal current of operating value is present in the relay winding.

16. In a signaling system, a plurality of pairs of three electrode vacuum tubes, means for applying signal voltages to the grids of the first tube of each pair in rotation, a plurality of differential relays each having windings respectively connected in the output circuits of each pair of tubes, a local source of potential, means for applying to each grid of said pairs of vacuum tubes a voltage from said local source simultaneously with a signal voltage, the voltage from the local source being effective to operate the relay only when no signal voltage of operating value is present.

17. In a signaling system, a plurality of pairs of three electrode vacuum tubes, means for applying signal voltages to the grid of the first tube of each pair in rotation, a plurality of differential relays each having windings respectively connected to the output circuits of each pair of said tubes, and normally arranged in balanced circuits, a local source of potential, means for simultaneously applying to each of the windings of one of said relays a voltage from said local source concurrently with a signal voltage, the voltage from the local source being effective to operate the relay only when no signal voltage is present, and coupling means between the output of one tube and the input of the other tube of each pair for varying the space current of said other tube in the opposite sense to the space current of the first tube, whereby the effective operating current of the associated relay is increased.

18. In a synchronous telegraph system, a

transmission line, a plurality of transmitters arranged in groups, means for interleaving the impulses of one transmitter with those of the other transmitters of the same group for transmission over said line, a plurality of pairs of three electrode vacuum tubes each pair arranged to receive all the impulses from one transmitter in each group, differential relays each having its windings respectively connected in the plate circuits of one of said pairs of vacuum tubes, said relays being responsive to a train of received impulses of one polarity, a movable armature and a pair of contacts on each relay, a source of potential having its opposite poles respectively connected to said contacts, printer relays each having a winding connected to one of said armatures, and impedance element associated with each of said printer relays for causing the operation of the next succeeding differential relay when the received impulses are of alternate positive and negative polarities.

19. In a synchronous telegraph receiving system, a local source of potential, a plurality of relays each having a movable armature operable between the contacts connected to opposite poles of said source, and having differentially operated windings, a pair of three electrode vacuum tubes associated with each relay, a plurality of sources of plate potential respectively connected to said relays through the windings, synchronous means for distributing received signal impulses to the grid of one tube of each pair to increase or decrease the space current therein in accordance with the polarity of the received impulses, and a condenser individual to each pair of vacuum tubes arranged between the plate circuit of one of said tubes and the grid circuit of the other of said tubes, whereby a change in space current in one tube is utilized to cause a change in the opposite sense to the space current in the other of said tubes, said changes in space current aiding in operating the armature of the associated relay to either of its associated contacts to repeat the signal.

20. In a synchronous telegraph receiving system a local source of potential, a plurality of receiving relays each having a movable armature operable between two contacts connected to opposite poles of said local source and having two differentially operated windings, a pair of three-electrode vacuum tubes associated with each relay, and connected through the windings thereof, a printer relay connected to each of said armatures, a resistance element connected to the windings of each of said printer relays and arranged to apply a regenerating voltage from said local source to the filament of the first tube of the next succeeding pair, synchronous distributing means for simultaneously applying the received signal voltages and regenerating voltages between the grid and filament of the first tube of each pair in rotation to vary the normal space current of said first tube, and condensers respectively connected between the tubes of said pairs for utilizing the changes in space currents of the first tube to effect a change in the opposite sense in the space current of the second tubes, said changes being utilized to increase the effective operating current in the relay, the changes due to the regenerating voltages being effective to operate the relays only when no signal impulses are received.

In witness whereof, I hereunto subscribe my name this 28th day of December, 1928.

WILLIAM A. KNOOP.