SIGNAL INTERPOLATING SYSTEM

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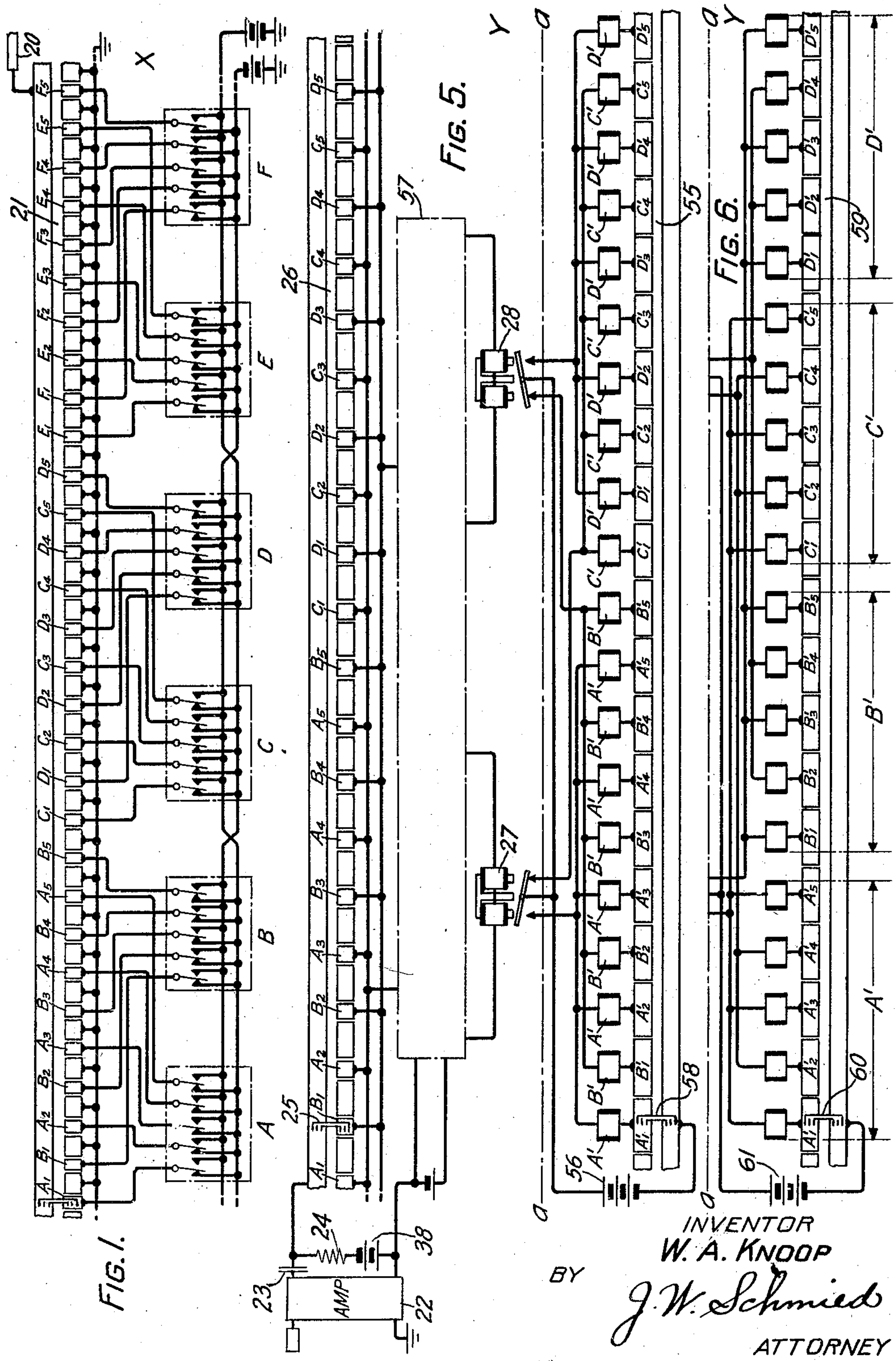

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SIGNAL INTERPOLATING SYSTEM

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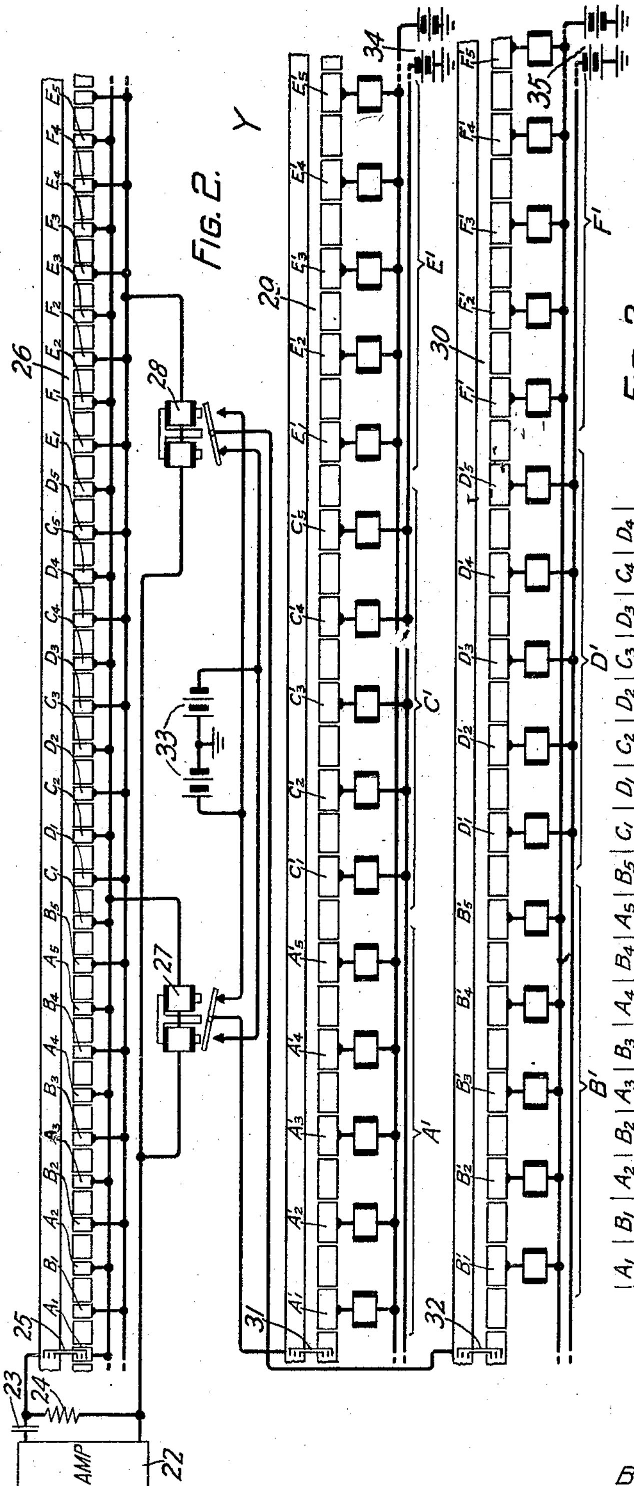

FIG. 2.

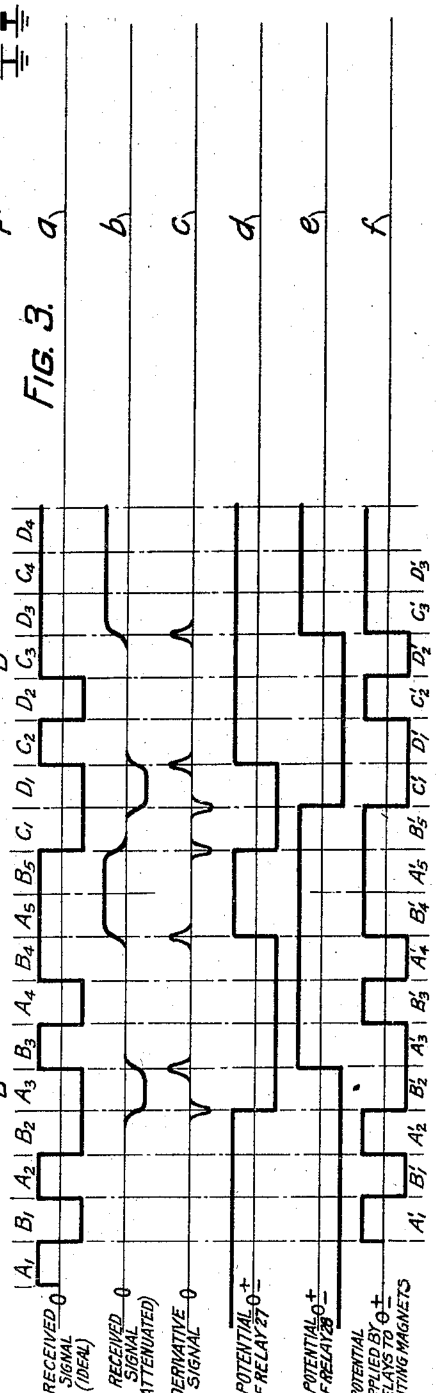

FIG. 3.

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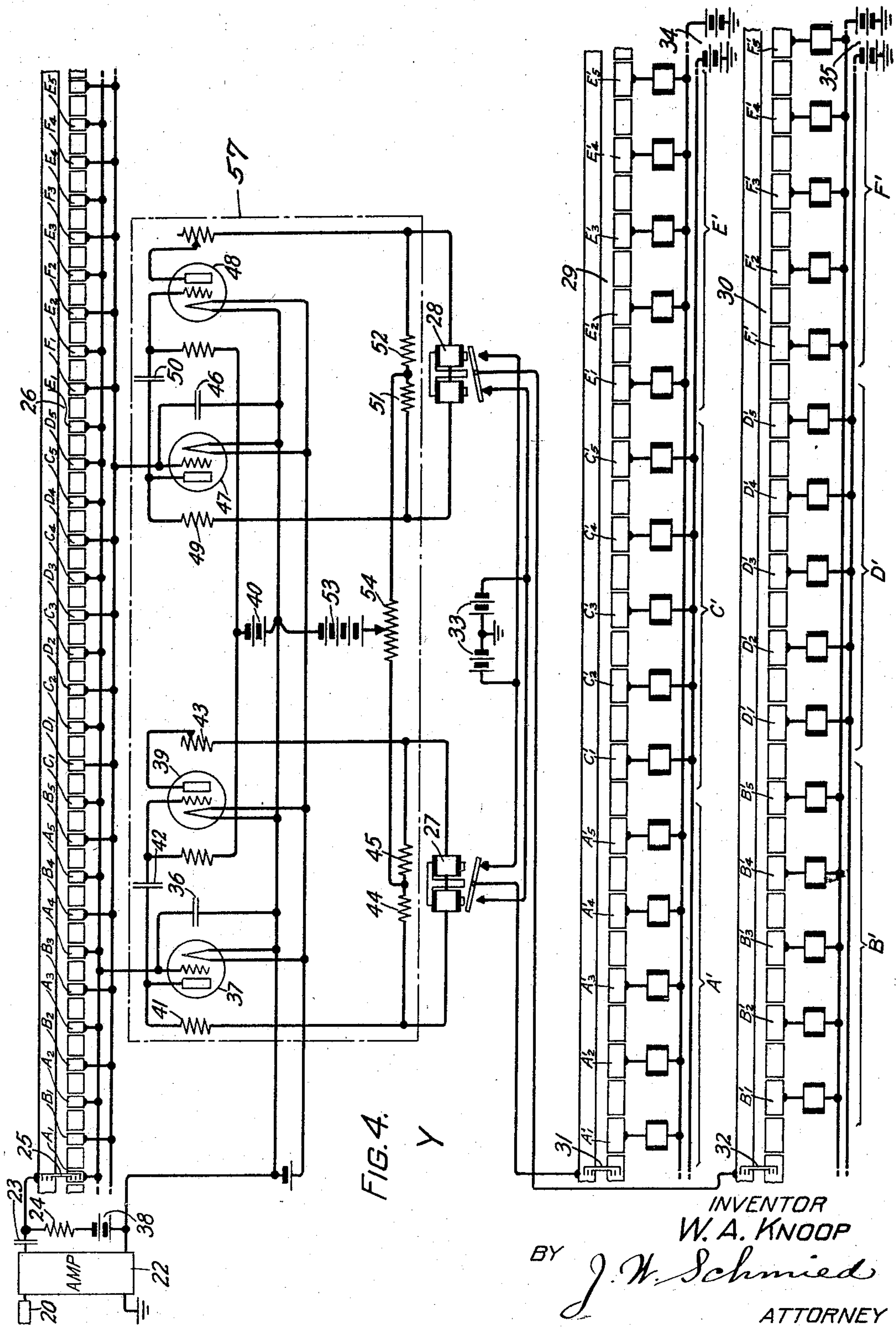

FIG. 4.

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April 7, 1931. W. A. KNOOP 1,799,627

SIGNAL INTERPOLATING SYSTEM

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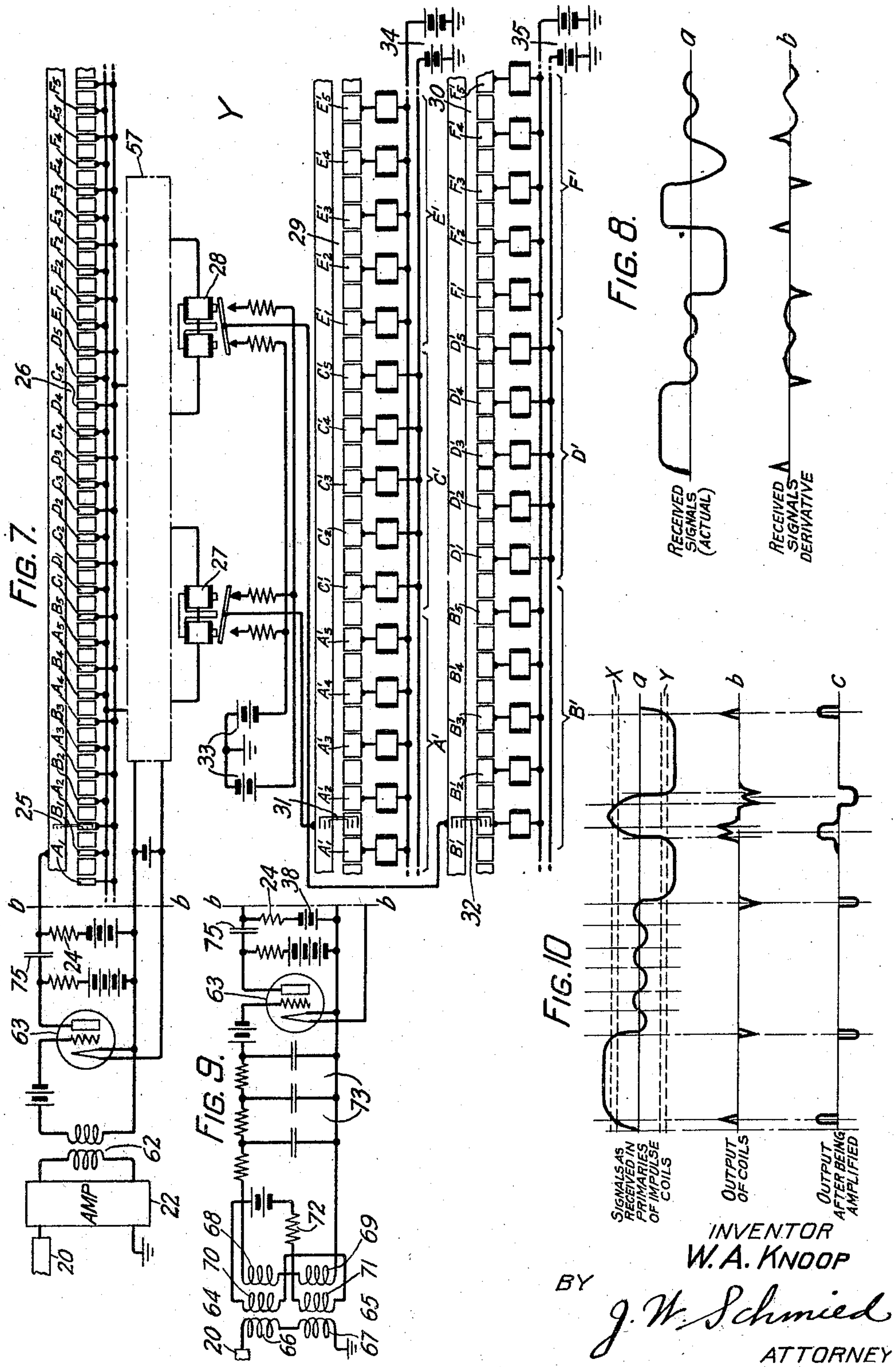

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Patented Apr. 7, 1931

1,799,627

UNITED STATES PATENT OFFICE

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SIGNAL-INTERPOLATING SYSTEM

Application filed February 28, 1929. Serial No. 343,452.

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

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

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

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, systems adapted to accomplish this purpose have have been commonly termed "vibrating relay systems". This expression is somewhat misdescriptive of the system of this invention because short impulses are rebuilt without necessarily vibrating any relay 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 have been practically completely attenuated during transmission.

Applicant's copending application Serial No. 329,439 filed December 31, 1928, discloses interpolating systems in each of which three or more receiving relays are employed, the relays being so arranged that the line voltages and interpolating voltages are superimposed on the same windings of each relay. The relays are arranged in rotation to simultaneously receive the incoming signal impulses and the interpolating voltages, the latter being of sufficient strength to operate the relays when and only when the incoming signal impulses are of unit length and of alternate positive and negative polarity. The interpolating voltages are generated by a local source of current and impressed on a circuit extending over the contacts of any one of the relays through a resistance wherein a voltage is regenerated and impressed on the winding of the next succeeding relay.

The systems of the present invention differ from those previously known in that only two receiving relay circuits of the type disclosed in the applicant's copending application, supra, are employed. These systems comprise arrangements in which the time derivative of the received signal impulses instead of the signal impulses themselves, are impressed on the relay windings. The derivatives or voltage impulses, particularly those resulting from the signal impulses which were transmitted as impulses of two or more units length, are of sufficient strength to operate the relays to opposite positions, whereby the relays in conjunction with the rotary distributor reproduce the signal impulses of two or more units length and produce when impulses of unit length are transmitted, impulses of alternate, positive and negative polarity, properly timed.

The line voltages only are impressed on the relay windings, whereas the interpolated impulses are produced over the relay contacts as the printer brushes rotate over their respective segments when the line voltage is of insufficient strength to operate the relays.

In the drawings Figs. 1 and 2 show a schematic circuit of an arrangement in which two receiving relays are employed to repeat the impulses from a plurality of groups of transmitters, there being two transmitters in each group. The impulses of each two transmitters are interleaved for transmission over the line, and are repeated through the receiving relays to their respectively associated printers over two separate distributor rings.

Fig. 3 shows curves representing the operation of the circuit arrangement shown in Figs. 1 and 2.

Fig. 4 is a modification of the receiving circuit shown in Fig. 2 wherein vacuum tube storing and impulse lengthening arrangements are used in conjunction with the receiving relays.

Fig. 5 is a modification of Fig. 4 wherein one pair of distributor rings is provided for the operation of the printers and the printer selector magnets are connected directly to the receiving relays.

Fig. 6 is a modification of Fig. 5 wherein the impulses from each transmitter are received consecutively, no interleaving of impulses being required.

Fig. 7 is another modification of Fig. 4 wherein the incoming line signals are received in the windings of a high permeability impulse coil and reproduced therein as short sharp voltage pulses, a pulse being produced every time the signal current passes through values slightly above and slightly below zero.

Fig. 8 shows the curves representing the operation of the circuit arrangement shown in Fig. 7.

Fig. 9 is a modification of Fig. 7 wherein the incoming line signals are received in the windings of two high permeability impulse coils connected in series and biased in opposite directions. The signals are reproduced in the coil windings as short sharp voltage pulses every time the signal current passes through values adjacent to that of the biasing current.

Fig. 10 shows the curves representing the operation of the circuit arrangement shown in Fig. 9.

Like parts are designated by like reference characters.

Description of the circuit of Figs. 1 and 2

Arranging Fig. 2 at the right of Fig. 1, a system is shown wherein six transmitters A, B, C, D, E and F at staton X are respectively connected in rotation over cable 20 to a corresponding number of printers designated A′, B′, C′, D′, E′ and F′ at station Y. The cable is designed for high speed transmission and in order that low sped 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. These relays may be substituted for the transmitters in a manner described in applicant's copending application, supra.

In order to repeat the high speed signals incoming at station Y, over a plurality of low speed lines, or if station Y is a terminating point, to the slow-acting selector magnets of the printers, the impulses from each group of transmitters are interleaved on the cable. This is because slow-acting repeating relays or selector magnets are not capable of responding to the impulses when received successively from each transmitter in rotation. The interleaving operation consists in connecting the transmitters of each group to the distributor 21 so that the impulses, one from each transmitter of a group, are sent successively until all five impulses of each transmitter of the group are sent. In other words, an impulse from transmitter A is followed by an impulse from transmitter B and this operation is repeated until all five impulses from transmitters A and B are sent. Transmitters C and D and E and F are similarly connected to the sending distributor 21 and these are operated in the same manner as that described above for transmitters A and B.

The impulses from transmitters A and B are received at station Y in an amplifier 22 (which may include shaping networks) and impressed on a small capacity condenser 23. Connected across the output circuit of the amplifier and in series with the condenser 23 is a comparatively small resistance 24. The output circuit is completed by brush 25 in rotating over the ring set 26. Therefore, the signal impulses are impressed on ring set 26 as voltage pulses of short duration, one pulse occurring at each rise and fall of a received signal. The ring set 26 is constituted of two rings, one continuous and one segmented. The segmented ring consists of alternate live and dead segments, the alternate live segments being interconnected to form two groups. These groups are respectively connected to receiving relays 27 and 28. These relays are of an unbiased polarized type. In this manner the receiving relays are arranged to be alternately connected to the cable 20 for that portion of the time when the incoming signals are rising and falling through their greatest amplitudes. In high speed operation the signals of unit impulse length are not present in the received signal and any impulse that operates a receiving relay must be one forming a part of a signal of at least two units in length.

The armatures of relays 27 and 28 are respectively connected to two printer ring sets 29 and 30, each of which comprises a continuous and a segmented ring. The segmented rings each consists of ten alternate live and dead segments for each transmitter so that for the six transmitters arranged in three groups, as shown, each segmented ring has thirty alternate live and dead segments. The printer rings are concentrically arranged with the receiving ring set 26, one brush arm being provided with the brushes for the three ring sets disposed in radial alignment. The live and dead segments of the printer ring sets are of the one length. 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 two ring sets 29 and 30 are so positioned with respect to the segments of receiving ring 26 that when a receiving brush 25 on ring set 26 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 a dead segment immediately at the left hand side of such corresponding live segment. In other words, should brush 25 be passing the center of segment A_3 of ring set 26, brush 31 would be in the center of the dead segment immediately to the left of segment A'_3. Therefore, in accordance with this arrangement of the live segments of ring set 26 and the corresponding segments of ring sets 29 and 30, printers A′, B′, C′, D′, E′ and F′ will be operated in sequence.

The interpolation of impulses at station Y to replace those of unit length which are lost or greatly attenuated during transmission, is effected by means of brushes 31 and 32 in rotating over their respective printer ring sets 29 and 30. When a long impulse, that is, one of two or more units length, is received, the current of the impulse does not begin to build up to a sufficient strength to operate a receiving relay, until the beginning of the second unit so that if two long signal impulses of opposite polarity are transmitted successively these impulses when they are received at station Y, will be separated by a zero interval of approximately one unit length. Condenser 23 and resistance 24, both of which have a comparatively low value, prevent the signal current itself from entering the relays but produce the first derivatives, with respect to time, of the long signal impulses, that is, a short, sharp voltage pulse at the beginning and at the end of each long impulse which are of sufficient strength to operate the relays. A derivative, as used herein, may be defined as a voltage or current pulse proportional to rate of change per unit of time in the voltage or current received from the amplifier 22. The voltage pulses thus produced by each long impulse are opposite in polarity to correspond to the rise and fall of the signal current producing them and are impressed on different live segments of the receiving set 26 so that the armatures of the relays 27 and 28 are, in response to the long impulses, always driven to opposite positions at the end of the impulse. The armatures are respectively connected to the continuous rings of printer sets 29 and 30. Inasmuch as the live segments of the segmented rings of printer sets 29 and 30 are respectively connected to printers A′ and B′ and the live segments for printers A′ and B′ are alternately engaged by their respective brushes, it is therefore seen that when no long impulses are being received, and if the relays are in opposite positions there will be generated, as brushes 31 and 32 rotate over their respective ring sets, unit length impulses of opposite polarity, the selector magnets of printer A′ receiving impulses of one polarity and those of printer B′ receiving impulses of the other polarity. Printers C′ and D′ and E′ and F′ are similarly affected.

The general practice of reversing polarity between certain channels or within channels, in order to produce a more perfect balance of polarities on a submarine cable in a multiplex signaling system, has been shown by reversing the battery leads of the transmitters shown in Fig. 1 at points between adjacent pairs of transmitters and also by reversing the battery leads of each of the two printer sets between printers as shown in Fig. 2.

Operation of the circuit arrangement of Figs. 1 and 2

Referring to Fig. 3 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 would be received at station Y without attenuation; curve *b*, the same wave as it is actually received at station Y with the impulses of unit length omitted; curve *c*, a wave showing the derivatives of the received impulses produced in the windings of relays 27 and 28 by the combined action of condenser 23 and resistance 24; curve *d* a wave indicating the potentials furnished by battery 33 over the armature of relay 27; curve *e*, a wave indicating the potentials furnished by battery 33 over the armature of relay 28; and curve *f*, a wave showing the potentials successively applied to the printers A′ and B′, C′ and D′, and E′ and F′, the last wave corresponding to the transmitted signal wave shown in curve *a*, but out of phase by one unit interval to represent the lag of the receiving equipment. In curve *a*, the first, second and third impulses are of unit length and of alternately opposite polarities but are so greatly attenuated that no effective current is received at station Y, as shown in curve *b*. The fourth and fifth transmitted impulses are of negative polarity and form a long impulse and therefore when this impulse is received and amplified at station Y it rises during the fifth impulse interval to a sufficient valve to produce by means of condenser 23 and resistance 24 two voltage pulses as indicated in curve c. The sixth and seventh transmitted impulses are each of unit length and therefore are not received. The eighth, ninth and tenth impulses are of positive polarity and form a long impulse which when received and amplified at station Y, rise to a sufficient value to form one impulse extending over the ninth and tenth intervals, thereby forming or producing through condenser 23 and resistance 24 two voltage pulses of opposite polarity as shown in curve c. The eleventh and twelfth impulses are of negative polarity and also form one long impulse of two units length which when received and amplified, rises to an effective value during the twelfth interval to produce two voltage impulses of opposite polarity as shown in curve c. Curve c therefore shows the first derivatives, with respect to time, of the received signal waves as applied in rotation to segments A_3, B_3, A_5, C_1, D_1, C_2, D_3, etc. The application of the derivative impulse to segment A_3 operates relay 27 to its negative position. The application of the opposite derivative to segment B_3 operates relay 28 to its positive position. The application of the positive derivative to segment A_5 operates relay 27 to its positive position. The application of the negative derivative to segment C_1 operates relay 28 to its negative position. The application of the negative derivative to segment D_1 operates relay 28 to its negative position and the application of the positive derivative to segment C_2 operates relay 27 to its positive position. Assume, for the purpose of illustration, that relays 27 and 28 and brushes 31 and 32 are in the positions shown in the drawing. As brushes 31 and 32 rotate and brush 31 engages segment A'_1 the positive pole of battery 33 is connected through the winding of the first magnet of printer A′ to the positive pole of battery 34, but the magnet does not operate. As brush 32 reaches segment B'_1 the negative pole of battery 33 is connected over the armature and left hand contact of relay 28 through the windings of the first selector magnet of printer B′ to the positive pole of battery 35 and this magnet of printer B′ operates. When brush 31 reaches segments A'_2 a positive potential from battery 33 is impressed over the armature and right hand contact of relay 27, through the windings of the second selector magnet of printer A′, and this magnet of printer A′ also remains unoperated. When brush 32 reaches segment B'_2 relay 28 is still in its negative position and a negative potential is therefore impressed on the second selector magnet of printer B′ to operate the second magnet of printer B′. When brush 31 reaches segment A'_3 a second unit of the first long signal impulse has been received and amplified as shown in curve b and has produced a negative voltage as shown in curve c to operate relay 27 to its negative position. A negative potential is therefore applied to the windings of the third selector magnet of printer A′ which effects its operation. As brush 32 approaches segment B'_3 the amplified current of the first long signal impulse has decreased to zero value which permitted the discharge of condenser 23 to produce a voltage impulse of positive polarity to thereby operate relay 28 to its positive position, and therefore the positive pole of battery 33 is connected to the positive pole of battery 35 through the windings of the third selector magnet of printer B′, but this magnet does not operate since the batteries are connected in opposition. When brush 31 reaches segment A'_4 relay 27 is still in the negative position and operating current flows through the windings of the fourth selector magnet of printer A′. When brush 32 reaches segment B'_4 relay 28 is still in a positive position and no current flows through the windings of the fourth selector magnet of printer B′. When brush 31 reaches segment A'_5 the current of the second unit of the second long impulse produces a voltage impulse through condenser 23, as shown in curve c, to operate relay 27 to its positive position, thereby impressing an ineffective positive potential on the fifth selector magnet of printer A′. When brush 32 reaches segment B'_5 the amplified signal current which remained at a steady value during the ninth and tenth impulse intervals, holds condenser 23 in a charged condition so that no impulse is produced to operate the relay 28 and therefore the relay causes an ineffective positive potential to be impressed on the windings of the fifth selector magnet of printer B′. This operation is continued for the printers C′ and D′ in accordance with the waves shown in curves a, b and c, except that the polarity of the effective potentials for the selector magnets is reversed between each pair of channels as shown in the connection of the printer magnets to batteries 34 and 35. Therefore, in accordance with the signal wave of curve a, only the third and fourth selector magnets of printer A′ and the first and second selector magnets of printer B′ are operated to produce the first two desired characters.

By arranging the armatures of relays 27 and 28 to be respectively connected in alternate order to the printers A′ and B′, then to C′ and D′ and E′ and F′ in turn, it may be readily seen from a study of curves d and e that by selecting the potentials produced by relays 27 and 28 as brushes 31 and 32 rotated over the live segments of their respective ring sets 29 and 30, a wave such as shown by curve f will be produced. It will be noted that this wave includes the impulses of unit length as transmitted from station X and, as stated above, resembles the wave of curve *a* except that it is out of phase with curve *a* by one impulse interval because of the time lag of the receiving apparatus.

Description of the circuit of Fig. 4

Arranging Fig. 4 at the right of Fig. 1 provides a system similar to that shown in Figs. 1 and 2 except that each of the relays 27 and 28 are operated through the action of a pair of three-electrode vacuum tubes wherein a normal balance of space current values is upset in order to control the operation of the relay associated therewith. In Fig. 4 the relays 27 and 28 are assumed to be in opposite positions so that when there are no signals being received at station Y the impulses which are interpolated will be alternate positive and negative polarity. Furthermore, when no signals are being received the normal balance of the space current values between the tubes of any pair remains unchanged, this balance being upset only when signals of two or more units length are received. Therefore the operation of the arrangement shown in Fig. 4 during the time when the impulses of unit length are ineffective to operate the relays 27 and 28, is identical with that described above for Fig. 2.

When the long negative signal, made up of the fourth and fifth impulses shown in curve *a* of Fig. 3, is received, the current of the second unit impulse during the fifth interval increases to an amplitude sufficient to produce a negative voltage across condenser 23. This potential is applied through ring set 26 by means of brush 25 passing over segment A_3, to condenser 36 and the grid of vacuum tube 37. Battery 38 is also applied through ring set 26 to the grid of vacuum tube 37 to give it a normal negative bias. The negative potential received from condenser 23 makes the grid more negative with respect to its associated filament and causes a negative charge to be stored on condenser 36. As brush 25 passes off segment A_3, the voltage stored on condenser 36 prolongs the negative potential impressed on the grid by the signal itself. Consequently, the normal space current in vacuum tube 37 is decreased. The second vacuum tube 39 of the first pair has its grid normally biased negatively with respect to its filament by a battery 40 and the variation in the space current of tube 37 is effective in a resistance 41 to cause a voltage drop to be produced across the resistance in such a direction that a negative potential is impressed on condenser 42 to make the grid of tube 39 less negative, thereby causing an increase in the normal space current of tube 39. Resistance 43 serves to balance the normal space current of tube 39 with that of tube 37. The windings of relay 27 are connected in series to the plate circuits of tubes 37 and 39 in such manner that the equal normal space currents of tubes 37 and 39 neutralize each other's magnetic effect on the relay. Connected in the plate circuit of tube 37 and in shunt to relay 27 is resistance 44 and in the plate circuit of tube 39 and also in shunt to relay 27 is resistance 45. Any changes in the space current of tubes 37 and 39 causes a difference of potential to occur across the windings of relay 27 and the relay operates to either of its contacts depending upon the direction of the voltage drop caused by the increase and decrease of the space currents of tubes 37 and 39. In the present case, the decrease in space current of tube 37 together with the increase in space current of tube 39 cause relay 27 to operate its armature to its left hand contact.

When brush 25 reaches segment B_3 the signaling current as shown in curve *b* of Fig. 3 decreases to zero which permits the discharge of condenser 23 and an impulse of positive potential is now applied to condenser 46 and grid of vacuum tube 47 of a second pair. Battery 38 is also applied to the grid of tube 47 to give it a normal negative bias but the positive potential applied by the discharge of condenser 23 makes the grid of tube 47 less negative with respect to its filament and the space current thereof is increased. The function of condenser 46 serves when brush 25 passes off segment B_3, to prolong the positive potential impressed on the grid of vacuum tube 47. The second vacuum tube 48 of the second pair has its grid normally biased negatively with respect to its filament by battery 40 and as the space current of tube 47 flows through a resistance 49 a voltage drop is produced across the resistance in such a direction that a positive potential is impressed on condenser 50 to make the grid of tube 48 more negative, thereby causing a decrease in the space current in tube 48. The windings of relay 28 are connected in series to the plate circuits of tubes 47 and 48 and in such manner that the normal space currents neutralize each other in the windings of relay 28. Resistances 51 and 52 are connected in the plate circuits of tubes 47 and 48, respectively, and any change in the voltage drop across these resistances upsets the balanced condition of relay 28 and causes it to operate its armature to either of its associated contacts in accordance with the predominating change in voltage. For instance, in the present case where the space current of tube 47 is increased and the space current of tube 48 is decreased because of the positive potential received over segment B_3 and brush 25, the armature of relay 28 moves to its right hand contact.

The interpolated impulses are produced in the same manner as described above for Fig.

2, where it was stated that the relays were operated to opposite positions at the beginning and end of each long signal impulse and the relays 27 and 28 were alternately connected to their respective printers A and B, C and D, and E and F in rotation.

In this arrangement in which pairs of vacuum tubes are provided for effecting the balance of opposite potentials across the windings of the receiving relays, it is possible to have a perfect balance across each relay, while the sensitivity of adjacent relays and their associated tubes will be different, and therefore in order to equalize the sensitivity of the relays 27 and 28, the plate battery 53 is adjustably connected to a resistance 54.

Description of circuit of Fig. 5

The arrangement shown in Fig. 5 is substantially the same as that shown in Fig. 4 except that a single printer ring set 55 is employed and the selector magnets of the printers are connected between the relay contacts and the live segments of ring set 55, the armatures of the relay being fixedly connected to positive battery 56. The vacuum tube circuits comprising elements 36, 37, 39 to 54, inclusive, as shown in Fig. 4, are represented diagrammatically by block 57. Assuming that the spacing and marking impulses from transmitters A and B at station X are positive and negative, respectively, relay 27 will operate to its left hand contact for each negative impulse received from station X and to its right hand contact for each positive impulse received. Therefore, in response to the marking or negative impulses, positive potential from battery 56 is furnished over the armature of relay 27 to operate the magnets of printer A′ in accordance with the marking impulses. Relay 28 will likewise operate to its left hand contact in response to the received marking or negative impulses to connect positive battery over its armature to the magnets of printer B′ in accordance with the received marking impulses. No magnets of printers A′ and B′ are operated in response to received spacing or positive impulses. Assuming likewise that the spacing and marking impulses in transmitters C and D are reversed in polarity, relays 27 and 28 will operate to their right hand contacts in response to received marking or positive signal impulses and to their left hand contacts in response to received spacing positive signal impulses, the magnets not responding when the relays operate to their left hand contacts. Relays 27 and 28 being in opposite positions during the times when no signals are being received, potentials of opposite polarities will be alternately applied to the magnets of printers A′ and B′, C′ and D′ etc. as brush 58 rotates over ring set 55.

Description of the circuit of Fig. 6

The system shown in Fig. 6 is similar to that of Fig. 5 and is shown in part only, it being understood that what is shown may be employed in place of the equipment shown below the line *a—a* in Fig. 5. Fig. 6 therefore represents a system which is the same as that represented by the schematic arrangement shown in Fig. 5 taken in conjunction with Fig. 1, except as noted below. The transmitters at station X are connected to cable 20 so that the impulses of each transmitter are consecutively transmitted instead of being interleaved with those of another transmitter as shown in Fig. 1. Accordingly, assuming that all transmitted impulses are received at station Y, the impulses from transmitter A are received on the first five live segments of receiving ring set 26; the impulses from transmitter B, on the second five live segments; and so on for the remaining transmitters. The live segments of ring set 26 are alternately arranged in two groups which are respectively connected to relays 27 and 28 like those shown in Fig. 5, but in this case each of the relays receive alternate impulses from each transmitter instead of all the impulses from a transmitter. The segments of printer ring set 59 are arranged so that the selector magnets of each printer in turn are capable of being consecutively connected by brush 60 to the armatures of relays 27 and 28.

The armatures of relays 27 and 28 are connected to the positive pole of battery 61 and the selector magnets of the printers A′, B′, C′, and D′ are operated in response to marking impulses transmitted from station X. The marking or operating impulses from transmitters A and C operate the relays to their left hand contacts and the marking or operating impulses from transmitters B and D operate the relays to their right hand contacts. The interpolated impulses are produced in the selector magnets in the same manner as described above except that only one printer ring set like in Fig. 5 is employed.

Description of the circuit of Fig. 7

The arrangement shown in Fig. 7 is another modification of Fig. 4 wherein an impulse coil 62 of the type disclosed in a copending application of E. T. Burton (Case 7), Serial No. 280,709, filed May 26, 1928, Fig. 7 of the drawings thereof, is employed in between cable 20 and the input circuit of vacuum tube amplifier 63. The nature of the impulse coil may be briefly described as a winding having a core of small cross-section of a high permeability material such as permalloy. The magnetic circuit of the transformer becomes saturated at a low amplitude of signal current in the primary winding and the inductance is consequently almost zero except when the core is demagnetized, that is at low signal amplitude. When the permeability is high, the inductance of the primary winding rises to a high value and there is produced in the secondary winding of the transformer a voltage impulse, the intensity and duration of which are regulated by the electrical constants of the transformer and the character of the signal in the primary winding. These voltage impulses, shown in the curve b of Fig. 8, are produced immediately before the magnetic circuit becomes saturated and are in the same direction as the input or signal current which produces the corresponding impulses. The voltage impulses produced in the secondary winding are impressed on the vacuum tube 63 wherein they are amplified, and passed without any appreciable effect through blocking condenser 75, which serves merely to block the passage of the direct current component of the amplified impulses. The remaining part of the arrangement shown in Fig. 7 functions the same as Fig. 4.

Description of the circuit of Fig. 9

Fig. 9 is a modification of that part of Fig. 7 to the left of line $b—b$ wherein two transformers 64 and 65 comprising impulse coils, are shown connected in series between cable 20 and vacuum tube amplifier 63. The transformer impulse coils are operated in a manner described in detail in the application of E. T. Burton, supra, and shown in Fig. 8 of the drawing thereof. Coils 66 and 67 represent the primary windings and coils 68 and 69 are the secondary windings. The transformers are biased by a direct current flowing in opposite directions through biasing windings 70 and 71. The opposite biasing windings prevent the signaling current flowing in the primary windings from producing an effective inductance until the magneto-motive force of the primary current becomes nearly equal, and opposite, to that of the current in either of the biasing windings. When these magneto-motive forces become equal the inductance rises to a high value almost instantly to produce a voltage impulse in one of the secondary windings. This voltage impulse is short and sharp because the magnetic circuit becomes quickly saturated or overloaded. Therefore, the signaling current is effective to produce a voltage impulse in either of the secondary windings only in those intervals in which the current is passing through the narrow range of values in the neighborhood of the biasing current amplitude, wherein the inductance rises to a high value. The inductance rises to such value twice in each positive and each negative sweep of the signaling current wave. In order to insure these voltage impulses being short and sharp a high impedance, such as a resistance 72 may be placed in series with the biasing windings. In order to provide an improved shaping for the secondary voltage impulses a resistance-capacity network 73 may be provided intermediate the transformers and vacuum tube amplifier 63.

Fig. 10 shows in curves a, b and c the primary current wave, the secondary voltage wave, and the secondary voltage wave after shaping and amplification, respectively. The dotted parallel lines x and y in curve a represent the ranges of amplitudes in which high inductance values are attained whereat the voltage impulses, shown in curve b, occur. Curve c shows the shape of the signal impulses desired to impress upon the storing condensers in the vacuum tube circuits diagrammatically represented by block 57. Condenser 75 is a blocking condenser which allows the signal to pass but blocks the direct current component of the voltage impulses in plate circuit.

What is claimed is:

1. An impulse transmission system in which impulses of unit length sent from a transmitter, but not received in effective amplitude, are regenerated, and impulses of plural unit length are received in effective amplitudes, characterized in this, that an even number of relays, each having its winding uncontrolled by the armature of the other, remain normally quiescent in opposite positions for the regeneration of unit impulses; a plural unit impulse of an odd number of units acts on each of the relays, one at the second unit and one at the end of the impulse to reverse their positions; and a plural unit impulse of an even number of units acts on one only of the relays, once at the second unit and again at the end of the impulse to reverse and restore its position.

2. In a telegraph system comprising a plurality of receiving relays, the method which comprises taking the derivatives produced at the beginning and end only of each received impulse and applying said derivatives in rotation to said plurality of receiving relays.

3. A synchronous interpolating system characterized in this that it comprises a line having a high attenuation characteristic for transmitting signals, a pair of relays, a single pair of distributor rings whereby said relays are alternately connected to said line, said relays being capable through the single pair of distributor rings of being operated by the first and last derivatives only, with respect to time, of each of the received impulses and of assuming relatively opposite positions when no signals are being received, and other means for further repeating the signals received from said line and inserting in the received signals impulses of alternately opposite polarity to replace the impulses that are lost during transmission over said line.

4. A telegraph system comprising a transmission line having a high attenuation char-

acteristic, a single pair of receiving distributor rings, a pair of relays arranged to be alternately connected to said line through said pair of distributor rings, and means connected between said line and said pair of distributor rings for producing in response to each received impulse which was impressed on said line as an impulse of two or more units length, a pair of short, sharp voltage impulses, one at the beginning and the other at the end of each received signal impulse, to operate said relays, the voltage impulse produced at the end of each received signal impulse being effective to set the relays in relatively opposite positions.

5. A telegraph system comprising a transmission line, a single pair of receiving distributor rings, two relays arranged to be alternately connected to said line through said pair of distributor rings, and a capacity-resistance network connected between said line and said pair of distributor rings for producing an impulse at the beginning and end of each received impulse to operate said relays, the impulse produced at the end of each received signal impulse being effective to set said relays in relatively opposite positions.

6. A telegraph system comprising a transmission line, a single pair of distributor rings, two relays arranged to be alternately connected to said line through said distributor rings, means connected between said line and said distributor rings whereby the derivatives only of the received signal impulses are utilized to operate said relays, said relays being operated to relatively opposite positions in response to the derivative produced at the end of each received signal impulse, and means for normally impressing across the windings of each of said relays equal potentials of opposite polarity whereby the relays are normally maintained unenergized, said means being effective in response to a signal derivative to vary the potential across the winding of either of said relays whereby the relay is operated to its opposite position.

7. A telegraph system in accordance with claim 6 characterized in that it comprises means for equalizing the sensitivity of said relays.

8. A telegraph system comprising a transmission line, a single pair of distributor rings, a pair of relays arranged to be alternately connected to said line through said distributor rings, capacity-resistance network connected between said line and said distributor rings whereby the derivatives only of the received signal impulses are utilized to operate said relays, said relays being operated to relatively opposite positions in response to the derivative produced at the end of each received signal impulse, a pair of vacuum tubes arranged in push-pull cascade arrangement for normally impressing across the winding of each of said relays equal potentials of opposite polarity whereby the relays are normally maintained unenergized, said vacuum tube arrangement being effective in response to a signal derivative to vary the potential across the winding of either of said relays whereby the relay is operated to its opposite position, and means connected in the circuits of said vacuum tubes for equalizing the sensitivity of said relays and said pairs of vacuum tubes.

9. A telegraph system comprising a transmission line, a single pair of receiving distributor rings, a pair of repeating devices arranged to be alternately connected to said line through said pair of distributor rings, and means connected between said line and said pair of distributor rings for producing the first and last derivatives only, with respect to time, of the received signal impulses to operate said repeating devices, the derivative produced at the end of each received signal impulse being effective to set the repeating devices in opposite positions.

10. In a multiplex telegraph system, a sending station and a receiving station, a transmission circuit interconnecting said stations, a plurality of transmitters at said sending station, means for applying signal impulses from said plurality of transmitters to said circuit in rotation, the impulses of one transmitter interleaved with those of another transmitter, a pair of receiving relays at said receiving station, and means at said receiving station for producing a signal derivative at the beginning and end of each received signal impulse and for applying the derivatives to said receiving relays, whereby the relays are operated to opposite positions in response to the derivative produced at the end of each received signal impulse, a plurality of printers arranged in pairs at said receiving station, a pair of printer distributor rings arranged to alternately distribute the impulses produced by said relays over each pair of printers in rotation.

11. A telegraph system comprising a transmission line, a single pair of receiving distributor rings, a pair of relays arranged to be alternately connected to said line through said pair of distributor rings, and means comprisng differentiating devices connected between said line and said pair of distributor rings for producing a signal derivative at the beginning and at the end of each received signal to operate said relays to opposite positions, said impulse coils being effective to produce the derivatives during any desired range of rising and falling amplitudes of the signal impulses of positive and negative polarities.

12. A telegraph system in accordance with claim 11 in which the differentiating devices include a network of impedance.

13. A telegraph system in accordance with

claim 11 in which the differentiating devices include capacity-resistance networks.

14. A telegraph system in which impulses of unit length sent from a transmitter but not received in effective amplitude, are regenerated, and impulses of plural unit length are received, characterized in this, that the impulses arriving are distributed among an even number of relays each having a single operating winding, alternate relays remaining normally quiescent in opposite positions for the regeneration of unit impulses, and are operated at times by derivatives only of the current impulses through their respective single operating windings.

In witness whereof, I hereunto subscribe my name this 26th day of February, 1929.

WILLIAM A. KNOOP.