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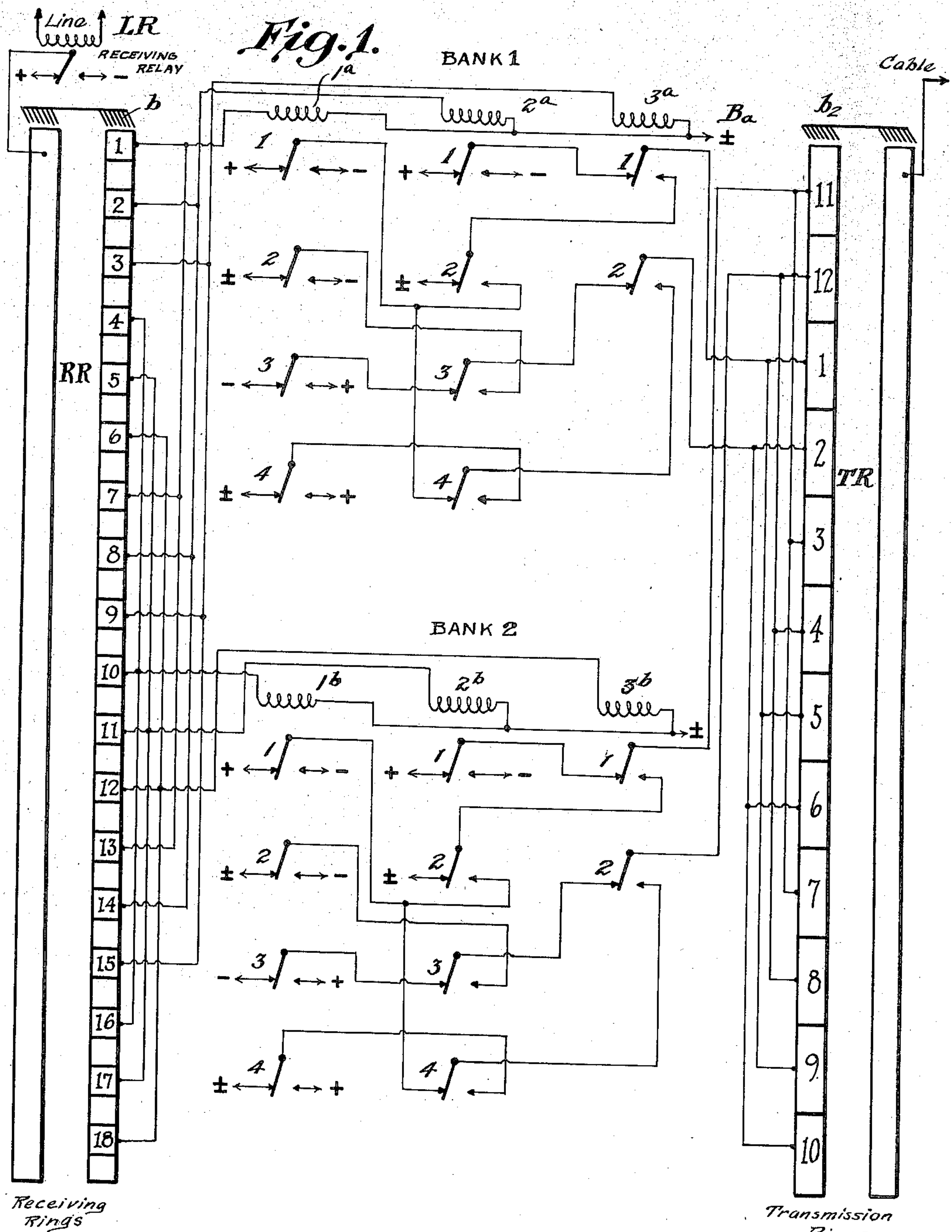
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SIGNAL CONVERSION IN TELEGRAPH SYSTEMS

Filed March 29, 1934

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

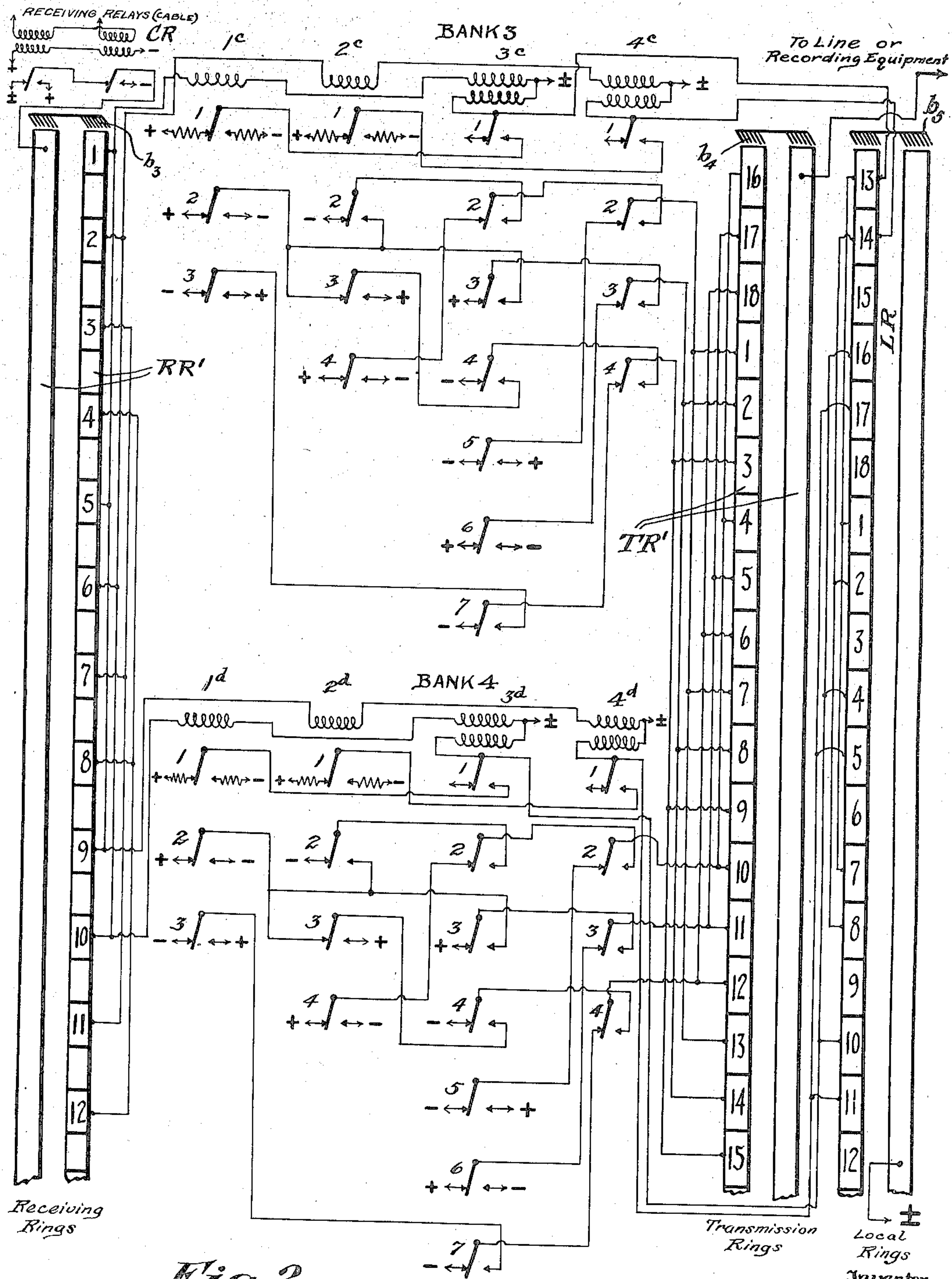


Fig. 2.

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SIGNAL CONVERSION IN TELEGRAPH SYSTEMS

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12 Claims. (Cl. 178—70)

This invention relates to telegraph systems and in particular to the conversion of one class of signals to another class of signals for transmission over a cable and the reconversion to the original signals at the receiving end for the purpose of facilitating the transmission.

As is known by telegraph engineers, cables which are provided with a wrapping of certain magnetic material around the cable conductor for the purpose of increasing the inductance and thereby neutralizing the distributed capacity, are referred to as "loaded" cables and are capable of transmitting the signaling current impulses at a much higher frequency than non-loaded cables. Loaded cables have a frequency range of from 50 to 100 cycles per second; while non-loaded cables, 2000 miles in length, have a safe frequency signaling range from 5 to 15 cycles per second.

Non-loaded cables do not lend themselves readily to the use of multiplex operation in which the two-current class of signals are normally employed for various reasons and are, therefore, normally operated with the three-current cable recorder code, sometimes referred to as cable Morse code.

One object of my invention is to provide a system for increasing the number of letters transmitted per minute over a non-loaded cable, while maintaining the stability and accuracy of the three-current recorder code (positive, negative and zero current), and at the same time have the advantages of the two-current (positive and negative current) five-unit multiplex code. I attain this object by a novel combination of the signals, providing means at the transmitting station for converting the five-unit two-current multiplex signals into the three-current signals for transmission over the cable and at the receiving station providing a similar means for converting the three-current signals back into the two-current signals.

Another object of my invention is to provide such a system wherein a minimum equipment is required at the cable repeater stations and in the event that it is desirable to revert completely to recorder code, only the transmitting and receiving stations will require a change in equipment.

From the three-current values of battery, positive, negative and zero, a total of nine combinations of two impulses each are obtained as shown in Chart A below:—

nations of two impulses each are obtained as shown in Chart A below:—

Chart A	Chart B
+ -	+ + +
+ +	- + +
- -	- - +
- +	+ - -
+ 0	+ + -
0 +	+ - +
- 0	- + -
0 0	

From a series of + and - battery signals, each of which is unit length, a total of eight combinations of three signals may be obtained Chart B shows the eight combinations.

Since a series of two-current signals divided into groups of 3-unit signals must necessarily fall into one of the groups shown in Chart B, the corresponding 2-unit signals of Chart A may be substituted for the 3-unit signals in Chart B, and 2-unit signals may be sent into the cable for the original 3-unit signals. It is obvious that a continuous succession of 2-current signals may be converted into 3-current signals in this manner with a corresponding reduction in the frequency of the signals sent into the cable.

The advantages of the system may be more clearly stated by reference to a given case. Suppose the capacity of a given cable is 300 letters per minute of 3-current recorder code. This speed would be equivalent to 1110 unit signals where a conversion factor of 3.7 unit signals per letter is used. The conversion factor is taken from an average of signals per letter in the cable Morse code sent over a commercial circuit. This is equivalent to 555 double signals similar to those shown in Chart A. Since every double unit of Chart A may represent a unit of three signals in Chart B, which again is equivalent to 3 units of a 5-unit multiplex code, these 555 double units represent 3×555 or 1665 single units of the multiplex code. In the multiplex code 5 single units represent one letter; therefore 1665 divided by 5 equals 333 letters, a gain of 33 letters per minute. The letters per minute transmitted and received at the terminal is therefore 3×3.7 divided by 5×2 or 1.11 times the normal recorder

code speed if a combination of the two codes is used in the circuit and at the same time the cable is operated at normal signalling frequency.

Figures 1 and 2 show the manner in which the conversion is made from one type of signals into the other. In Fig. 1 the two-current signals (marking and spacing conditions only) are converted into the three-current signals (marking, spacing and no-current conditions). Normal two-current signals operate relay LR. The tongue of relay LR is connected to a set of distributor rings. The segmented ring is divided into a multiplicity of segments and three consecutive segments are connected respectively to the winding of three relays. The segments are further grouped in such a manner that alternate sets of three segments are associated with alternate sets of three relays. In this manner three signals are received to operate the first relay bank and the next three signals operate the relays of the second bank. Such an arrangement provides for the necessary overlap to prevent distorted retransmission.

The relays of each bank are of the multi-tongue and contact type and may be either polar or neutral relays. As shown in Figure 1, the circuit is arranged for polar relays. For neutral relay operation the return of the windings would be brought to either + or - battery and provision made to lock up and unlock the relay at the proper intervals, as will be evident.

The tongues and contacts of each bank of three relays are arranged to establish circuits, so that the two tongues of the third relay of each bank which are connected to the segments of the transmission set of rings, supply the proper three-current impulses to these segments. Signals are sent into the line from these segments by means of the solid ring and brushes associated with this set of rings.

In Figure 2 the arrangement is similar to that of Figure 1 and the circuit shown is for the conversion of three-current signals (permutations of marking, spacing and no-current signal conditions) back into two-current signals (permutations of marking and spacing conditions only). As shown, alternate sets of two impulses are received to operate alternate banks of four relays. Two of these relays, one polar and one neutral relay, are associated with each signal. In this case, also, neutral relays may be substituted for the polar relays with the proper circuit changes made for the operation of neutral relays. The circuits established by the tongues of these relays impress upon the segments of the transmission set of rings through the tongues of relay 4, three impulses of 2-current signals which are of the proper sequence of polarity and identical with the polarity received in Figure 1 to operate the relays for the conversion into two impulses of 3-current signals.

The operation of the system will be clear from an example. Suppose in Fig. 1 that signals are being received on the line relay LR. The operation of the tongue of this relay in accordance with line signals causes battery to be supplied to the solid ring of the receiving rings RR of the rotary distributor. The circuit includes battery, tongue and contacts of the line relay LR and the solid receiving ring. Suppose the brushes *b* spanning the solid and segmented rings RR are at the #1 segment of the segmented ring. And suppose the signal received is + battery and that this impulse is three units in length. The

brushes, in making contact with segment 1, establish a circuit from + battery, through tongue and contacts of the line relay LR, the winding of relay 1^a of the relay bank #1 to the mid point of battery B_a. This causes the tongues of relay #1 to be positioned to their left hand contacts. Likewise, as the brushes pass to segment #2, the tongues of relays 2^a of bank 1 are positioned to their left contacts and as the brushes pass over segment #3, the tongues of relay 3^a are operated to their left contacts. The polarity or battery supplied to segments 1 and 2 of the set of transmitting rings TR is determined by the position of the tongues of the three relays of the relay bank #1. These circuits may be traced: From positive battery, left contact and tongue 1 of relay 2^a; left contact and tongue 1 of relay 3^a to segment #1 of distributor rings TR. Positive battery is, therefore, applied to segment #1 of distributor rings TR. Also from negative battery, tongue and left contact 3 of relay 1^a, tongue and left contact 3 of relay 2^a; tongue and left contact 2 of relay 3^a to segment 2 of distributor rings TR. The battery set-up on segments 1 and 2 of rings TR is therefore + - which, by reference to Chart A and Chart B, is the designated combination for three positive (+ + +) signals.

The brushes *b*₁ associated with rings TR revolve at the same rate as do the brushes associated with rings RR, and when the brushes associated with rings RR make contact with segment 4 of rings RR, the brushes associated with rings TR make contact with segment 1 of rings TR. While the brushes pass over segments 1 and 2 of rings TR, segments 4, 5, and 6 of ring RR are also bridged in sequence by the brushes *b* associated with these rings and the next combination of three-unit signals received from the line relay LR cause the operation of relays 1^b, 2^b, 3^b, respectively, of bank 2. The output of relay bank 2 is connected to segments 3 and 4 of rings TR as shown. Since relay bank 2 is similar to bank 1, the operation of this bank is the same as described for bank 1.

The third received group of three signals would be impressed on segments 7, 8, and 9 of receiving rings RR and would again cause the operation of the relays of relay bank 1. Suppose this third group of signals is + - -, that is, one unit of positive battery and two units of negative battery. The tongues of relay 1^a of bank 1 would remain on their left contacts, since the previous position of these tongues was to the left. Relays 2^a and 3^a would have their tongues positioned to the right hand contacts in response to the negative impulses. The polarity of battery supplied to segment #5 of rings TR would be positive, through a circuit from left contact and tongue 1 of relay 1^a, right contact and tongue 2 of relay 2^a, right contact and tongue 1 of relay 3^a. The battery polarity supplied to segment #6 of rings TR would be from mid point of battery, through the circuit from left contact of tongue 4 of relay 1^a; right contact and tongue 4 of relay 2^a; right contact and tongue 2 of relay 3^a to segment 6. The battery set-up on segments 5 and 6 of rings TR is therefore + 0 which is that designated in Charts A and B as the proper combination for a signal + - -; i. e., one positive and two negative unit impulses. During the time the relays of bank 1 were operated from segments 7, 8, and 9 of receiving rings RR the signal impulses set up on segments 3 and 4 of

rings TR from bank 2 were transmitted into the cable.

It should be kept in mind that whenever the mid-point of battery is connected to the line the transmission potential is the same potential as the return of the circuit to battery hence no current is transmitted and the signal interval is designated as a zero signal.

In Figure 2 the circuits for the conversion from three-current signals into two-current signals is shown. The motion of the brushes associated with rings RR' and rings TR' of the rotary distributor are similar to that described in Figure 1. If the same signals are received by the receiving relays of Figure 2 as were transmitted from rings TR of Figure 1, the first group of two signals would be + -; i. e., one positive and one negative impulse. The operation of the receiving relays of Figure 2 will supply to the solid ring RR', from the battery and tongue circuits of these relays, the same polarity as is received from the line or cable. The operation of a set of receiving relays as shown is fully known to those familiar with the art of signalling for three-current signals and hence no description is necessary.

As the brushes b_3 associated with rings RR' pass over segment 1, a circuit is established from + battery (as assumed above) through the tongue circuit of the cable receiving relays CR to solid ring, through brushes b_3 and segment 1 of rings RR' through the windings of relays 1^c and 3^c in series to the split or midpoint of battery. Relay 1 is of the polar type and its tongue is operated to the left contact by a positive signal. Relays 3^c and 4^c are neutral relays and their tongues are operated to the right hand contact on either positive or negative signals, and remain on the left contact on zero signals.

The tongues of relay 3^c are therefore operated to their right contacts on the reception of the positive signal. A circuit is established from positive battery through the left contact and tongue 1 of relay 1^c through the right contact and tongue 1 of relay 3^c through the locking winding of relay 3^c to split or mid-point of battery. This circuit causes relay 3^c to remain in its operated position for the duration of the locking circuit.

The next signal to be received is the negative impulse of the group + -. As the brushes pass over segment 2 of cable receiving rings RR', a circuit is established from negative battery through the tongues and contacts of receiving relays CR, rings RR' and brushes b_3 through the windings of relays 2^c and 4^c of bank 3. Relay 2^c has its tongues positioned to the right contacts and tongues of relay 4^c, a neutral relay, is also operated to the right contact. With the tongues of relays 1, 2, 3, and 4, Figure 2, positioned as described, battery circuits are established to segments 1, 2, and 3 of rings TR' as follows:

From positive battery, through left contact and tongue 2 of relay 1^c, right contact and tongue 2 of relay 2^c, right contact and tongue 2 of relay 3^c, right contact and tongue 2 of relay 4^c to segment 1.

From positive battery, through tongue 2 and left contact of relay 1^c, right contact and tongue 3 of relay 3^c, right contact and tongue 3 of relay 4^c to segment 2.

From positive battery, through right contact and tongue 3 of relay 2^c, right contact and tongue 4 of relay 3^c, right contact and tongue 4 of relay 4^c to segment 3.

The signal set up on the relays for transmission

from segments 1, 2, and 3 of distributor rings TR' is therefore + + +, which is the two-current signal (marking and spacing conditions only), used to obtain the + - signal in the three-current signal (embodying marking, spacing and no-current signal conditions), in the supposition used under the description of operation in the circuits shown in Fig. 1.

After brush b_4 passes over segments 1, 2, and 3 of rings TR' and thereby transmits the signal into the line, brush b_5 makes contact with segments 1 and 2 of local rings LC and short-circuits the locking winding of relays 3^c and 4^c, respectively, by the application of the midpoint of battery from solid local ring through the brushes and segments to the tongues 1 of relays 2^c and 4^c. These relays are thus restored to the unoperated position ready for the next selection.

The operation of bank 4 is from segments 3 and 4 of rings RR', and the output of bank 4 is connected to segments 4, 5, and 6 of rings TR'.

No means have been shown to maintain synchronism between stations and it is understood that such means common to the art are employed. The operation of the synchronizing circuit, including distributors, is similar to any other circuit using rotating means, such as distributors, for the regeneration and repeating of telegraph signals. This invention relates solely to the conversion of one type of signals into a second type and the restoration of the signal back into its original type signal.

The circuit has been described with relays but it is obvious that any electrical or electro-mechanical device embracing an eight range selecting mechanism may be substituted for the relays shown in banks 1 and 2 of both Figures 1 and 2.

The circuits shown in Figures 1 and 2 apply only to the reception, conversion and transmission of a given signal and no attempt has been made to show the complete circuit from the transmitter or transmitters to the receiving printer or printers or other recording equipment. Such circuits are not considered part of the invention and are familiar to all who are acquainted with the art of automatic telegraphic communication.

It will be understood by those skilled in the art that the disclosure, as shown in Figures 1 and 2, is an arbitrary arrangement of the invention and that its use, although described in the foregoing text partly in terms of the 2-current five-unit multiplex code and the use of non-loaded cables, it is not limited to such but is applicable to any signalling system involving the use of 2-current signals, irrespective of the unit length of code and irrespective of the physical medium constituting the signalling circuit.

It will also be understood by those familiar with the art that the number of segments in each distributor ring and the number of relay banks of Figures 1 and 2; the 2-current input circuit shown as line and relay LR, Figure 1, and the 2-current output circuit involving distributor rings TR' of Figure 2, will vary in accordance with known conditions of each circuit. For instance, to preserve channel identities in 5-unit code multiplex circuits, the distributor rings, Figures 1 and 2, will be divided into multiples of five segments, the number of segments in the 3-current signal ring are $\frac{2}{3}$ of the number of segments in the 2-current ring.

I claim:

1. The method of increasing the letters per minute transmitted over a cable, which consists in converting each three successive units of 2-current signals (embodying permutations of marking and spacing signal conditions) into two successive 3-current signals (embodying permutations of marking, spacing, and no-current conditions) without regard to code characters, transmitting them over the cable, and reconvert-
 10 said 3-current signals at the receiving end into the original 2-current signals for retransmission or recording, said reversion being definite to a conversion key arbitrarily arranged in accordance with mathematical combinations possible
 15 in groups of two and three-element signals irrespective of any definite code.

2. The method of increasing the letters per minute transmitted over a cable, which comprises
 20 converting 2-current signals taken in arbitrary groups of a fixed number of signal units, irrespective of code length, into 3-current signals of two-thirds the number of signal elements in accordance with a predetermined conversion key,
 25 and transmitting said converted signals over said cable, said conversion key being based on a mathematical relationship between the two-element and three-element signals and being irrespective of any definite code.

3. The method of increasing the letters per minute transmitted over a cable, which comprises
 30 converting 2-current signals taken in arbitrary groups of a fixed number of signal units, irrespective of code length, into 3-current signals of two-thirds the number of signal elements in accordance with a predetermined conversion key,
 35 transmitting said converted signals over said cable and reconvert-
 40 ing the received signals transmitted over the cable into their original 2-current code, said conversion key being based on a mathematical relationship between the two-element and three-element signals and being irrespective of any definite code.

4. The method of increasing the letters per minute transmitted over a telegraph line, which
 45 consists in dividing any series of two-current signals of any code length into constant length groups of two-current signals, converting said
 50 groups into constant length groups of 3-current signals for transmission over a telegraph circuit, reconvert-
 55 ing said 3-current groups into said two-current signal groups and restoring said signals of said 2-current groups into the original series of code signals, said reversion being definite
 to a conversion key arbitrarily arranged in accordance with mathematical combinations possible
 in groups of two and three-element signals irrespective of any definite code.

5. In a telegraph system, including a non-loaded cable, a multiplex distributor having
 60 transmitting rings connected to the cable, a line relay adapted to receive multiplex two-current code signals and feed them into one or more channels of the receiving rings of said distributor,
 65 and means associated with said distributor for converting said multiplex two-current code signals into three-current signals in accordance with a predetermined conversion key, the conversion
 70 constant with respect to the signals converted being irrespective of the length of the received multiplex code signals, said conversion being irrespective of code combinations.

6. In a telegraph system including a non-loaded cable, a multiplex distributor having re-

ceiving and transmitting rings, adapted respectively to receive signals and transmit them to said cable, and means associated with said distributor for converting two-current received signals into three-current signals for transmission
 5 into the cable, said conversion being irrespective of code combinations, said conversion having a definite ratio with respect to the two and three element signals and being indefinite with respect
 10 to the length of the two element code.

7. In a telegraph system including a non-loaded cable, a multiplex distributor having receiving
 and transmitting rings, adapted respectively to receive signals and transmit them to said cable,
 15 and means interposed between said receiving and transmitting rings for converting two-current received signals into three-current signals for transmission into the cable, said conversion being
 20 irrespective of code combinations, said conversion being in the ratio of three to two and no multiple thereof.

8. In a telegraph system including a non-loaded cable, a multiplex distributor having receiving
 and transmitting rings, adapted respectively to receive signals and transmit them to said cable,
 25 and relays intermediate said rings, which are controlled by the received signals for converting two-current received signals into three-current signals for transmission into the cable, said conversion being
 30 irrespective of code combinations, said relays being operated in accordance with a conversion key unrelated to the code units of the two element code signals received.

9. In a telegraph system including a line and a cable, a multiplex distributor connected to receive
 35 signals from the line, means for converting marking and spacing signal conditions received from the line into marking, spacing and no-current signal conditions, and means for transmitting said converted signals to the cable
 40 through said distributor, said conversion being irrespective of code combinations, the conversion of any element of marking and spacing conditions into marking, spacing and no-current conditions being indefinitely determined.

10. In a telegraph system including a line and a cable, a multiplex distributor connected to receive
 45 signals from the line, means for converting marking and spacing signal conditions received from the line into marking, spacing and no-current signal conditions, irrespective of code combinations, said conversion being
 50 irrespective of code combinations, means for transmitting said converted signals to the cable through said distributor, a receiving distributor connected at the distant end of the cable to receive said converted
 55 signals, and means for reconvert-
 60 ing the marking, spacing and no-current conditions into the original marking and spacing signal conditions and transmitting them through said distributor, said reversion being performed after every two signal units received.

11. In a telegraph system including a cable, a multiplex distributor connected to receive code
 65 signals, means for converting marking and spacing code signal conditions received by said distributor into two-unit signals embodying permutations of marking, spacing and no-current conditions irrespective of code combinations, said
 70 conversion being irrespective of code combinations and means for transmitting said converted signals to the cable, said reversion being definite to a conversion key arbitrarily arranged in accordance with mathematical combinations

possible in groups of two and three-element signals irrespective of any definite code.

12. In a telegraph system including a cable, a multiplex distributor connected to receive signals from the cable, means for converting two-unit signals embodying marking, spacing and no-current signal conditions received by said dis-

tributor into three-unit signals embodying only marking and spacing signal conditions irrespective of code combinations, said conversion being irrespective of code combinations, and means for transmitting said converted signals through said distributor to a line or recording means. 5

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