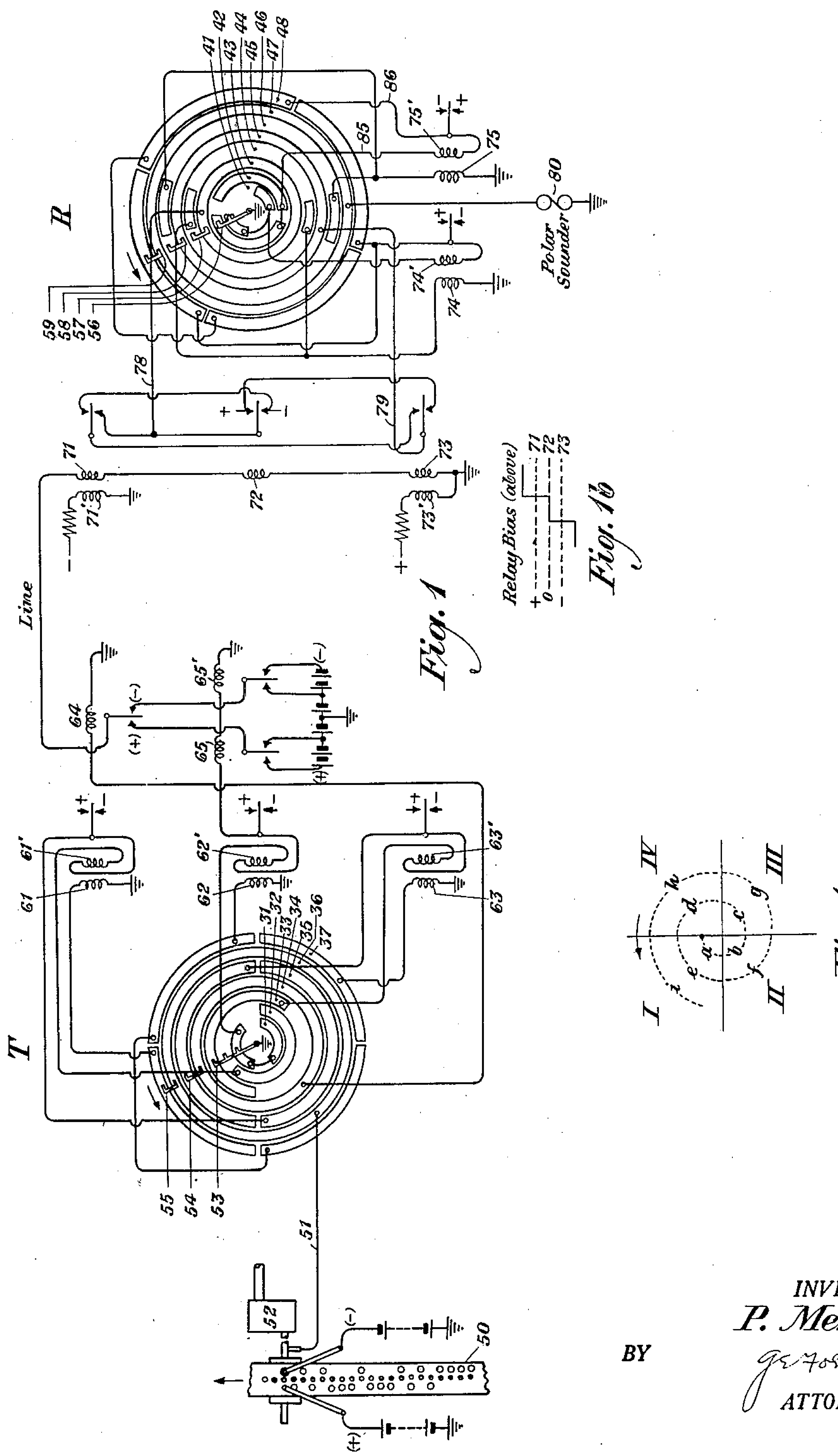
Oct. 1, 1929. P. MERTZ 1,729,645

SIGNALING SYSTEM

Filed Jan. 7, 1928 4 Sheets-Sheet 1



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SIGNALING SYSTEM

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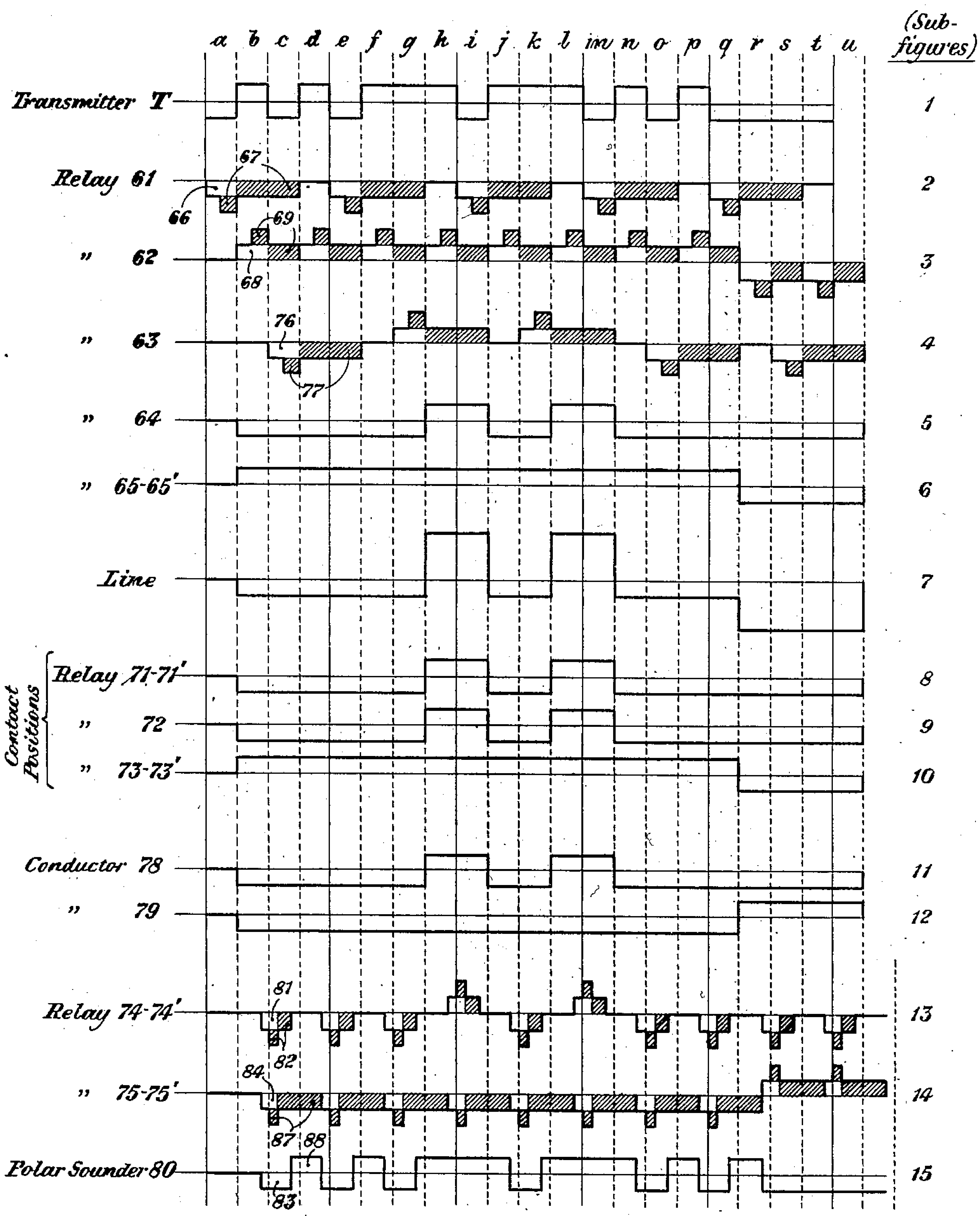

Note: Ordinates Represent: Voltage in Conductors.
Ampere Turns in Relays (except for sub-figures 8, 9 & 10)

Fig. 2

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SIGNALING SYSTEM

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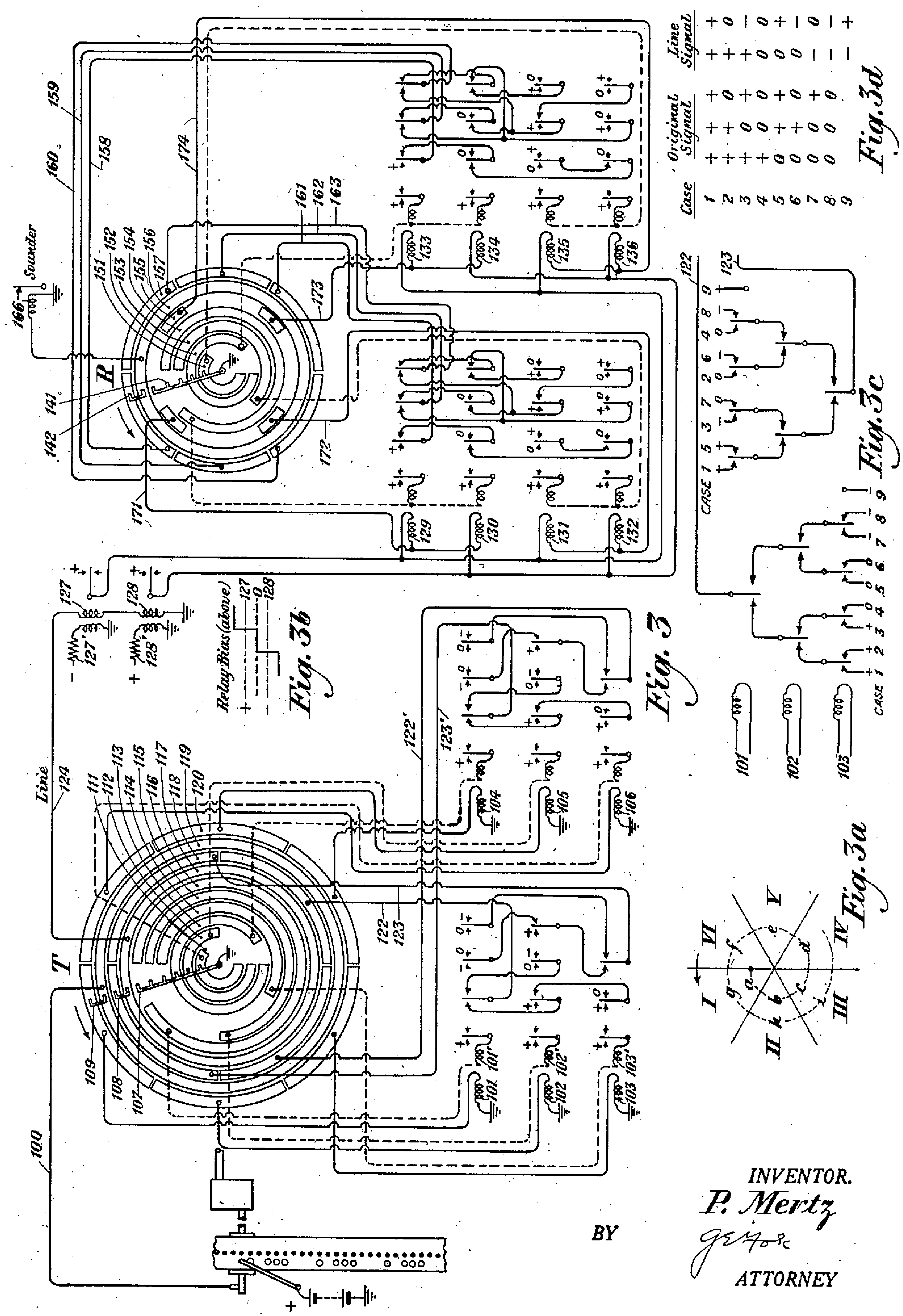

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SIGNALING SYSTEM

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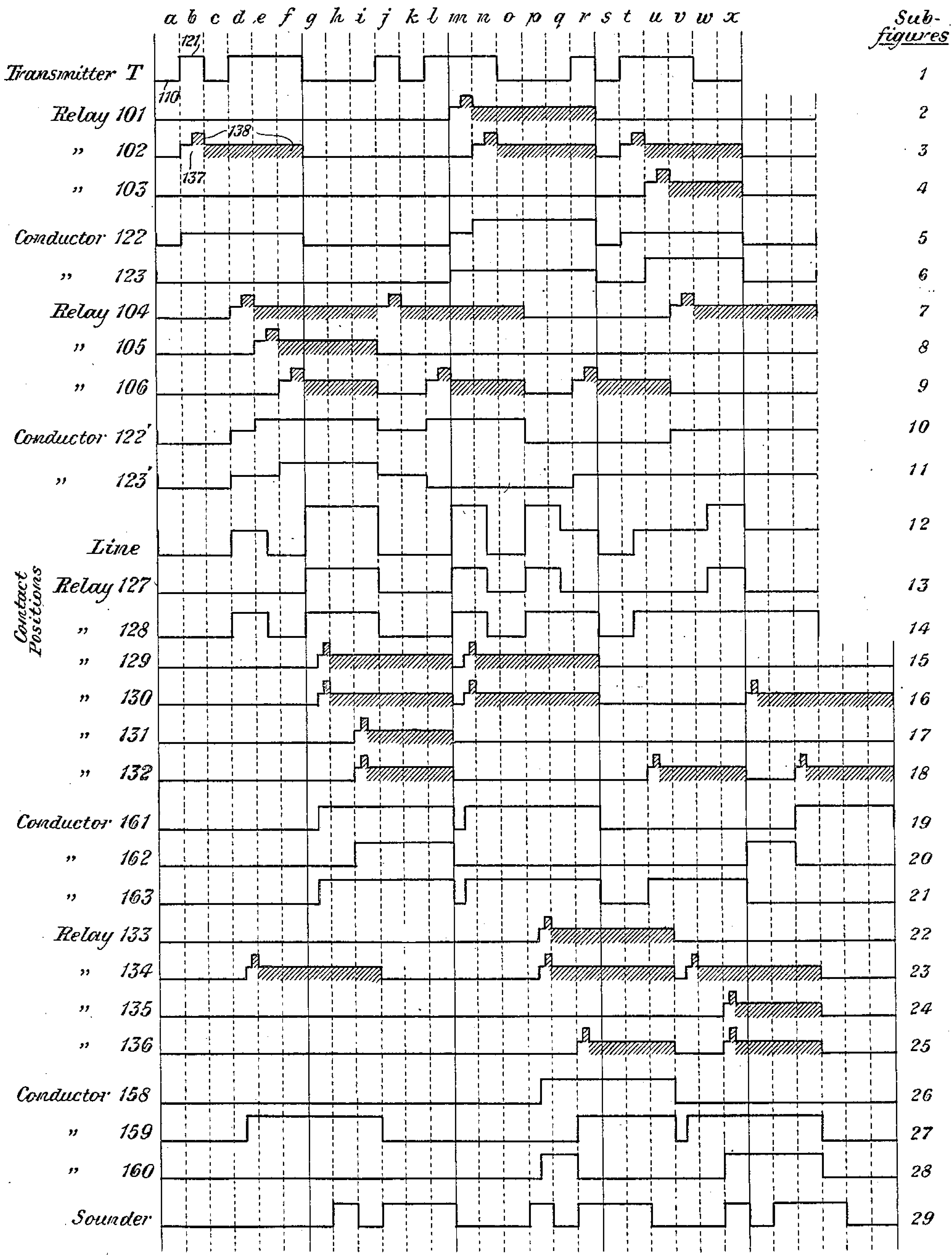

Note: Ordinates Represent: Voltage in Conductors. Ampere Turns in Relays (except for sub-figures 13 & 14).

Fig. 4

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Patented Oct. 1, 1929 **1,729,645**

UNITED STATES PATENT OFFICE

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SIGNALING SYSTEM

Application filed January 7, 1928. Serial No. 245,129.

In the transmission of intelligence by signaling, the capacity of a system will depend on the number of signal elements per second (half this quantity is commonly called the "dotting" speed or the signal speed), and on the number of possible kinds of signal elements that can be discriminated in an interval for one signal element. In some cases, it will be desirable to change a message so as better to adapt it for transmission over available apparatus by diminishing the signal speed and at the same time increasing the number of possible distinguishable signal elements, or vice versa. It is an object of my invention to provide for making such a change; that is, to change the number of signal elements per second one way and make the proper corresponding change in the number of distinguishable signal elements the other way. This object and other objects of my invention will become apparent on consideration of the following discussion of two specific cases of practice according to the invention, which I have chosen for presentation here by way of example.

Referring to the drawings, Figure 1 is a diagram of apparatus that may be employed in the practice of my invention under certain circumstances; Figs. 1^a and 1^b are diagrams to accompany Fig. 1; Fig. 2 is a coordinate diagram showing how the various parts of the apparatus of Fig. 1 operate for a train of signals; Fig. 3 is a diagram of apparatus for a case somewhat different from Fig. 1; Figs. 3^a, 3^b, 3^c and 3^d are diagrams ancillary to Fig. 3; and Fig. 4 is a coordinate diagram for the successive stages of operation of the various parts of the apparatus of Fig. 3.

In a signaling system in which successive signal elements are sent in respective equal time intervals, say n such intervals per second, $n/2$ is called the "signal speed." In each signal interval of one nth of a second the signal element must have at least two possible distinguishable characters, and may have more. Suppose for example that these distinguishable signal characters are current magnitudes considered algebraically so that positive and negative currents of equal measure are deemed to be of different magnitude. Let the number of such distinguishable magnitudes be C. Then, for a given amount of intelligence to be transmitted in a given time, the condition is C^n=constant. It will readily be seen that if a certain signal speed is to be halved, then the number C must be squared; if the signal speed is to be reduced to one-third, then C must be cubed, etc.

In the example of the invention represented in Figs. 1 and 2, a signal train for which C=2 and n has a certain value is converted for transmission into a signal train in which C=4 and n is half said value. Such an initial signal train is represented by sub-figure 1 in Fig. 2 (Fig. 2 (1)), where each signal element is either plus a unit of current or minus a unit of current. This signal train is transmitted in the form shown in Fig. 2 (7) where there are only half as many signal elements in the same period of time but each element may have any one of four different current values represented as -3, -1, $+1$, $+3$.

At the receiving end, the signals of the character shown in Fig. 2 (7) are converted back to the initial form and manifested as shown in Fig. 2 (15).

The message to be sent from station "west" in Fig. 1 is punched in the tape 50, shown at the left of Fig. 1, which is driven by the apparatus 52. The transmitting distributor T is also driven in synchronized relation with the tape 50, so that the distributor arm 53—54—55 makes one cycle for four successive positions of the tape 50; that is, the tape 50 steps ahead one position when the arm is up, when to the left, when down, and when to the right.

At the receiving end, the arm of the receiving distributor R moves in synchronism with the sending arm at T. This synchronism may be effected by suitable, well-known means not here disclosed. Further details of structure and the mode of operation of the apparatus shown in Fig. 1 will be made clear in the following description of the cycle of operations for transmitting several successive signal elements.

Starting with the distributor arm at T in the "up" position, call the ensuing signal intervals a, b, c, etc., and the corresponding quadrants swept over by the signal arm I, II, III and IV. Let the signal element in the period a be a "spacing" element, represented at a in Fig. 2 (1) as a unit of negative current. This means that negative battery is applied through the tape 50 and over the conductor 51 to the distributor ring 36, brush 55, segment of ring 37 and relay winding 61, whose armature is accordingly put to negative battery. When the brush 53 makes contact with the end of the segmental ring 32 in quadrant I, a holding circuit is completed from this negative battery through the relay winding 61′, ring 32 and brush 53 to ground, and this holds through the remainder of quadrant I and all of quadrants II and III. The pick-up current through winding 61 already mentioned is represented by the area 66 in Fig. 2 (2), and the holding current through winding 61′ is represented by the shaded area 67 in the same figure. Thus, the impulse in time interval a is stored in relay 61—61′ through the succeeding time intervals b and c.

The pick-up current through relay winding 61 is interrupted when the distributor arm passes from quadrant I to quadrant II at the end of signal interval a and the beginning of interval b. At this instant, the brush 54 engages the end of the lower segment of ring 35 and puts to the relay 64 the negative battery associated with relay 61—61′, throwing its armature to the right, as represented in Fig. 2 (5). Also, at this same instant, the tape 50 steps forward one stage and cuts off negative battery and applies positive battery to the conductor 51 and thence through ring 36, brush 55, segment of ring 37 to relay winding 62. Its armature is accordingly thrown up, thus applying positive battery directly to the windings of relay 65—65′ and moving its armatures to the left, as indicated in Fig. 2 (6). This puts one unit of negative battery on the line, as indicated in Fig. 2 (7). The pick-up current through the relay winding 62 continues during and only during the traverse of quadrant II by the arm of distributor T, but when the brush 53 engages the end in that quadrant of a segment of ring 31, the holding circuit is completed from positive battery through the relay winding 62′ to ground; and this holding circuit is maintained until the end of time interval c, that is, when the distributor arm passes from quadrant III to quadrant IV. The pick-up current in the winding 62 is represented by the area 68 in Fig. 2 (3), and the holding current in winding 62′ is indicated by the area 69.

Thus, it will be seen that the two successive signal elements a and b, determined by the tape 50, determine respectively the operation of relays 64 and 65—65′ throughout the double time interval b—c, and accordingly determine the current magnitude on the line through that double interval b—c. During the two successive intervals a and b, there are four possible initial signal combinations $++$, $+-$, $-+$, and $--$; the third of these is actually represented in Fig. 2 (1). These four different combinations will determine, respectively, the positions of the armatures of relays 64 and 65—65′ so as to put units of battery on the line as follows: $+3$, $+1$, -1, and -3. Thus, for each possible combination of two successive signal elements a and b in the tape 50 there will be put on the line a certain corresponding magnitude of current throughout the time intervals b and c.

When the arm of distributor T passes from quadrant II to quadrant III, neither relay 61 nor 62 can be utilized because both of these must store impulses throughout quadrant III. In quadrant III or time interval c, the signal impulse is negative, as represented in Fig. 2 (1), and accordingly negative battery is applied through the tape 50, over conductor 51, through ring 36, corresponding segment of ring 37 and relay winding 63, whose armature is accordingly put on negative battery. This pick-up current in relay winding 63 is represented by the area 76 in Fig. 2 (4). When the distributor arm reaches the middle of the third quadrant, the brush 53 engages the segment of ring 33 and puts negative battery through the relay winding 63′, ring 33 and brush 53 to ground. The current that flows is a holding current for the relay 63—63′ and is represented by the shaded area 77 in Fig. 2 (4).

When the distributor arm passes from quadrant III to quadrant IV, the holding circuits for relays 61—61′ and 62—62′ are broken, and the corresponding circuits heretofore described for relays 64 and 65—65′ are broken. At once, a circuit is closed from the negative battery with relay 63—63′ through the upper half of ring 35, brush 54, ring 34 and the winding of relay 64, thus throwing (or holding) its armature to the right. This represents the effect of the impulse that was stored initially in relay 63—63′. Also, when the distributor arm passes from quadrant III to quadrant IV, the tape 50 steps forward one position and cuts off negative battery and applies positive battery to the conductor 51, as represented at d in Fig. 2 (1); the circuit is made through ring 36 and the corresponding part of ring 37 and relay winding 62, causing its armature to put positive battery to the relay windings 65 and 65′, thus throwing (or holding) their armatures to the left.

With the description that has gone before, it will readily be seen how the impulses for time intervals c and d, now set up respectively in relays 63—63′ and 62—62′, will be stored and held throughout time intervals d and e and will determine the operation of relays 64 and 65—65′, respectively, and determine the magnitude of current on the line throughout the double period d—e.

Thus, each successive pair of two-value elements of the original signal train is converted into a single four-value element that is operative during the time interval of the second element of the pair and the first element of the next succeeding pair.

At the receiving end, the impulses on the line go through the three windings 71, 72 and 73 of respective relays. Associated with the winding 71 is a biasing winding 71′ with two units of negative current so that the critical current value in winding 71 for the operation of this relay is +2 units of current; in other words, the armature of relay 71—71′ goes up for currents above +2 units and down for currents less than +2 units. The relay 72 is unbiased and the relay 73—73′ is biased oppositely to 71—71′.

Following out the specific cycle of operations already traced at the sending end, the current on the line for the double interval *b—c* is one unit negative, as represented in Fig. 2 (7). Accordingly, throughout the interval *b—c* the relay armatures will be down for 71—71′, down for 72, and up for 73—73′, as shown in Fig. 2 (8, 9, 10). Thus, the negative battery associated with relay 72 will be applied to rings 43 and 45 in multiple over the respective conductors 78 and 79, as shown in Fig. 2 (11, 12). The currents in these two conductors correspond, respectively, with those in relays 64 and 65—65′ at the sending end, except that the current in 79 is reversed as compared with 65—65′.

The conductors 78 and 79 are connected, respectively, throughout time period *b—c* to the appropriate batteries through the armature contacts of relays 71—71′, 72 and 73—73′, and for a brief time at the middle of this period *b—c*, the distributor effects connections completing the circuits from said batteries through to respective relays 74—74′ and 75—75′ as will be pointed out presently. This is according to approved practice by which at the receiving end the signals are picked off at the middle or approximate peaks of the incoming signal impulses.

When the receiving arm of the receiving distributor R has nearly completed quadrant II, the said two branch circuits will be completed, respectively, by brush 57 engaging the lower segment of ring 44 and thus connecting through the relay winding 74, and by brush 58 connecting with the segment of ring 46 and thence through the relay winding 75. Accordingly, the armature corresponding to relay winding 74 will engage the negative battery and the armature corresponding to relay winding 75 will engage positive battery. This arrangement of polarities compensates for the reversal shown and mentioned for Fig. 2 (12) as compared with Fig. 2 (6). The current from negative battery associated with relay winding 74 will flow through lower segment of ring 48, brush 59, ring 47 and the polar sounder 80. The pick-up current in the winding 74 is represented by the unshaded area at 81 in Fig. 2 (13). A corresponding holding current through the winding 74′, that flows while the brush 56 engages the ring segment 41, is represented by the shaded area 82 in Fig. 2 (13). The current through the polar sounder 80, that flows while the brush 59 engages the lower segment of the ring 48, is represented by the area 83 in Fig. 2 (15).

At the same time that current began to flow in the winding 74, as just described, it also began to flow in the winding 75 from the negative battery associated with relay winding 72, over the conductor 79, ring 45, brush 58 and ring segment 46. This current is represented by the unshaded area 84 in Fig. 2 (14). Its effect is to put positive battery to the corresponding armature from which the two conductors 85 and 86 extend in multiple, but no circuit will be closed on either of them until the brush 56 engages ring segment 42 at the instant of transition from quadrant II to quadrant III. Thereupon, a holding current flows through the winding 75′. This lasts until the distributor arm reaches nearly to the end of quadrant IV and is represented in Fig. 2 (14) by the shaded area 87.

When the distributor arm has traversed nearly the whole of quadrant III, its brush 59 engages an end of a segment of ring 48 and closes a circuit from the positive battery associated with relay 75—75′ through conductor 86, segment of ring 48, brush 59, ring 47 and polar sounder 80, thus giving a positive signal impulse in the polar sounder 80 which is represented by the area 88 in Fig. 2 (15).

In view of the foregoing description, it will be readily understood how further successive double period signal impulses received from the line are analyzed and separated to the relays 74—74′ and 75—75′ and thence taken off in succession to the polar sounder 80.

In the foregoing example of practice according to my invention, we deal with a line which is best adapted for a certain comparatively slow signal speed and with four possible distinguishable signal elements in each signal interval, together with transmitting and receiving apparatus which is most advantageously operated at double the signal speed of the line and with only two possible distinguishable signal elements per signal interval. These two signal speeds are commensurable and the relation between them and the other factors involved is shown in the equation C^n=constant by the fact that starting with C=2 and doubling C and halving n preserves the equality with the constant unchanged. But suppose we have a line in which the signal speed is not so simply related to the signal speed in the terminal apparatus. For example, suppose that in the terminal apparatus the signal speed is a certain value for two distinguishable signal characters and that we want to operate at a signal speed reduced just enough to take advantage of three distinguishable signal characters on the line. Accordingly, from the fundamental equation heretofore mentioned, we should have $2^n=3^{n/r}$ where r will be the ratio of the signal speed of the terminal apparatus to the signal speed on the line. Solving this equation for r, the result is obtained that $r=1.585$ approximately. This ratio is incommensurable and shows the practical impossibility of transforming the signals exactly in the case supposed. It is possible, however, to secure automatic transformation at the expense of a slightly lower ratio in signaling speeds, that is, by wasting the available signaling facilities in some small degree. We might choose an integral ratio approximating in some degree to the ratio r (and necessarily less than r), but the next lower integer is 1, which represents no transformation whatever of the signal. It is possible, however, to translate the signals from the original to an intermediate form involving an integral ratio in signal speeds and then to translate again from the intermediate to a third form involving another integral ratio in signal speeds so that the resultant combination of the two integral ratios will approximate to and be slightly less than the desired ratio r. For example, starting with $C=2$, we have 2^n=constant where half of n is the signal speed. Evidently $8^{n/3}$=same constant where now the number of distinguishable signal elements is increased from 2 to 8 and the signal speed is decreased from half of n to half of $n/3$. This expression $8^{n/3}$ is approximately equal to but somewhat less than $3^{2n/3}$, and comparing the initial expression 2^n with the final expression $3^{2n/3}$ we have $r=1.5$ which approximates roughly to the ideal value mentioned heretofore, namely $r=1.585$. Figs. 3 and 4 are based on this approximation, $r=1.5$; the apparatus is shown in Fig. 3 and the operation of its parts is shown in time sequence in Fig. 4. It would be possible to secure a closer approximation to this ideal ratio at the expense of greater complexity in the apparatus.

The general principle of operation involves dealing with groups of three successive signal elements, (each of two possible values) as represented in Fig. 4 (1); and for each such group putting on the line two signal elements (each of three possible values), as represented in Fig. 4 (12).

As in the case of Figs. 1 and 2, the transmitting distributor T and the receiving distributor R operate in synchronism, by virtue of means not here disclosed, but well known and available. Each revolution of a distributor arm takes place in six time intervals for the message in its initial and final form, as shown in Fig. 4 (1) and Fig. 4 (29). I refer to the corresponding angular divisions of the sweep of the distributor arm as sextants I to VI, as indicated in Fig. 3^a. Three successive impulses are stored in the relays 101, 102, 103, and the next three such impulses are stored in the relays 104, 105 and 106. While these impulses are being stored in the second set of relays, two successive impulses each one and one-half times as long as an initial impulse are being put on the line through the transmitting distributor T, as determined by the stored impulses in the first set of relays; and whereas the initial impulses are each of only two possible values, the impulses put on the line are each of three possible values.

In the case considered in connection with Figs. 3 and 4, the two values for each initial impulse are zero and a positive unit of current. These impulses go from the transmitter over conductor 100, through ring 119, brush 109 and corresponding segment of ring 120 to the respectively connected relay windings 101 to 106. Accordingly, the first impulse of Fig. 4 (1), which is of zero current as represented at 110, leaves all the armatures for relay 101 on their back-stops, as indicated in Fig. 4 (2). The second signal impulse at 121 in Fig. 4 (1) puts the armatures for relay 102 on their front-stops, as indicated at 137 in Fig. 4 (3) and so on for all six relays 101 to 106, as shown in Fig. 4 (2, 3, 4, 7, 8, 9).

Holding circuits as shown in dotted lines in Fig. 3 are provided for the respective relays and are not energized or are energized according as the relay armatures remain on their back-stops or are drawn to their front-stops. Thus, for example, at the middle of the second signal impulse 121 of Fig. 4 (1), the brush 107 engages the segmental ring 115 and grounds the positive battery associated with relay 102, so that its current flows through auxiliary winding 102′ and holds the relay closed from the middle of sextant II until the end of sextant VI, as shown by the shaded area 138 in Fig. 4 (3).

Thus, the first three impulses of Fig. 4 (1) are set up initially in relays 101, 102 and 103, respectively, as the distributor arm sweeps through sextants I, II and III and remain stored as it goes on through sextants IV, V and VI. These three relays 101, 102 and 103 determine eight different combinations for their armatures from which the two conductors 122 and 123 lead away. The eight different combinations mentioned are indicated symbolically in Fig. 3^d. Each combination determines one of three different current magnitudes to be applied to each of the conductors 122 and 123, namely, plus a unit of current, zero, or minus a unit of current. Three different magnitudes on each conductor 122 and 123 give nine combinations for both conductors. These are represented in the right-hand part of Fig. 3[d]. A simple systematic arrangement of the armatures for the relays 101, 102 and 103 so that the eight different combinations therein will determine correspondingly eight of the nine possible combinations of current magnitudes in conductors 122 and 123 is as shown in Fig. 3[c]. It will at once be apparent in Fig. 3[c] that many of the contacts are superfluous, and the practical arrangement of the armature connections shown in Fig. 3 is correspondingly simplified mechanically as compared with Fig. 3[c]. Also it will be noticed that one of the nine possible line signal combinations of Fig. 3[d], namely − +, is not utilized. This represents wasted line capacity due to the approximation involved in changing from C=2 to C=3 as pointed out heretofore.

Accordingly, at the end of sextant III, one of eight different possible combinations has been set up in relay windings 101′, 102′ and 103′, and any one of eight different combinations of three current magnitudes each has been determined in the positions for the armatures of these relays for application to the conductors 122 and 123, as indicated in Fig. 4 (5, 6). When brush 108 passes from sextant III to sextant IV, it connects conductor 122 through ring segment 118 and ring 117 to the line 124, and, through the ensuing 90° travel of the distributor arm, current of one of the three possible magnitudes goes over the line, as indicated in Fig. 4 (12). At the middle of sextant V, the brush 108 passes from one segment of ring 118 to the next segment, thus disconnecting the conductor 122 from the line and connecting conductor 123 to the line and again during the next 90° travel of the distributor arm one of three possible current magnitudes is applied to the line as indicated in Fig. 4 (12) and as determined by the positions of the armatures of relays 101 to 103.

Thus, for the initial signal train shown in Fig. 4 (1) with three successive impulses, *a*, *b*, *c*, each of two possible values, there are put on the line two signal impulses each of three possible values, as shown in Fig. 4 (12).

While the separate impulses in relays 101 to 103 are being sent in sextants IV to VI, the initial signal impulses *d*, *e*, *f* are being set up and stored in relays 104 to 106, as indicated in Fig. 4 (7, 8, 9), and these determine one of three battery strengths applied respectively to conductors 122′ and 123′, as indicated in Fig. 4 (10, 11), and two successive line impulses are sent accordingly as the distributor arm sweeps through the succeeding three sextants I, II and III. Thus, the signal impulses are regrouped and transformed and put on the line as indicated in Fig. 4 (1) to (12).

At the receiving end, these impulses are delivered to the windings 127 and 128 of respective polar relays biased respectively with a unit of negative current and a unit of positive current in the respective auxiliary windings 127′ and 128′. Accordingly, these relays will be operated at the current levels shown in Fig. 3[b], and as indicated in Fig. 4 (13, 14). It will be apparent from the diagram of Fig. 3 that each signal impulse received from the line in the relays 127 and 128 will determine one of three different possible combinations of positions for their armatures which combination will become effective in the relays of one of the four pairs of relays 129 and 130, 131 and 132, 133 and 134 or 135 and 136 when the circuit of such pair of relays is grounded through conductor 171, 172, 173 or 174, respectively. We have already seen how the three initial signal impulses *a*, *b* and *c* of Fig. 4 (1) determine the two successive line impulses in the time interval *d*—*e*—*f* in Fig. 4 (12). The first of these two line impulses, being zero, puts the armature of relay 127 down and the armature of relay 128 up, as indicated in Fig. 4 (13, 14), while the brush of the receiving distributor R sweeps over sextant IV and the first half of sextant V. At the middle of this range of 90°, the short segment of ring 155 (at the lower right) is grounded by brush 141, thus putting the battery associated with relay 128 through the winding of relay 134, but leaving the battery with relay 127 on open circuit, so that the winding of relay 133 is not energized. Accordingly, the armatures of relay 134 are attracted to their front-stops, but those at 133 are left on their back-stops. At the middle of this 90° range, the brush 141 engages the end of ring segment 152 and closes a holding circuit (shown dotted) through to the end of the time interval *i*. Thus, the engagement of the brush 141 with the short ring segment 155 determines the energization of relays 133 and 134 through from about the middle of time interval *d* to the end of time interval *i*, as indicated in Fig. 4 (22, 23).

Similarly, the next following impulse in the line during the last half of time interval *e* and all of *f* determines a position for the armatures of relays 127 and 128, and impulses are picked off accordingly by brush 141 from the segment of ring 155 in sextant VI, thus determining the positions of the armatures of relays 135 and 136, as shown in Fig. 4 (24, 25), and so on for succeeding line impulses, the next one being stored in relays 129 and 130, (Fig. 4 (15, 16)) and the next after that in relays 131 and 132 (Fig. 4 (17, 18)).

The two signal impulses on the line in the time interval *d*—*e*—*f*, as shown in Fig. 4 (12), accordingly determine, at the end of that time interval, the positions of the relay armatures of the relays 133, 134, 135 and 136, and thus determine whether zero or positive battery shall be applied to each of the three conductors 158, 159 and 160, as indicated in Fig. 4 (26, 27, 28). These three conductors are connected respectively to segments of ring 157 in sextants I, II and III; and hence, as the brush 142 sweeps over these three ring segments, it puts these batteries of either zero or positive value successively to the sounder 166 and gives signal elements accordingly in time intervals, g, h, i, as shown in Fig. 4 (29) corresponding to the initial signal impulses a, b, c, shown in Fig. 4 (1). Similarly the initial signal elements at the sending end in time intervals d, e and f are eventually stored so as to determine the battery strengths put to respective conductors 161, 162 and 163 throughout period j—k—l, as shown in Fig. 4 (19, 20, 21), and in the respective intervals j, k, l, impulses are taken in succession from the segments of ring 157 through brush 142 and ring 156 to sounder 166 which is actuated as shown in Fig. 4 (29).

I claim:

1. In the transmission of signals consisting of a sequence of signal elements of equal duration and a certain definite number of such elements per second, the method which consists in increasing the number of signal impulses per second, making them of equal duration and correspondingly decreasing the number of recognizable characters for each impulse and transmitting the impulses accordingly.

2. In the transmission of signals consisting of a sequence of signal elements of equal duration, and of a certain definite number per second, the method of changing the signals better to adapt them for transmission over a part of the transmitting system, which consists in changing the number of signal elements per second in the signal train and correspondingly changing the duration of each impulse, making the impulses of equal duration and correspondingly changing the number of recognizable characters for each impulse.

3. In the transmission of a sequence of signal elements of equal duration each having any one of several recognizable characters, the method which consists in transforming such sequence to another sequence having a different number of signal elements per second of equal duration and an inversely different number of recognizable characters for each signal element.

4. In the transmission of a sequence of signal elements, the method which consists in converting a signal train from n signal elements per second of equal duration, each having C recognizable characters, to a signal train having a number different from n of signal elements per second of equal duration and a number correspondingly different from C of recognizable characters for each signal element.

5. In the transmission of signals over a system having two different parts, the method which consists in transmitting through one part at the best signal speed and with the optimum number of distinguishable characters per signal element for that part, the signal elements being of equal duration, then between the two parts converting the signal train to the best signal speed and the corresponding optimum number of distinguishable characters per signal element for the remaining part of the system, the signal elements being of equal duration, and transmitting therethrough accordingly.

6. In the transmission of a train of signal elements at a certain signal speed and with a certain number of distinguishable characters for each signal element, the method which consists in storing and superposing successive signal elements and transmitting other signal elements at less signal speed but with a greater number of distinguishable characters for each element.

7. The method of signaling, which consists in storing successive signal impulses in different relays and transmitting over the line a group of superposed effects determined by said relays.

8. The method of signaling, which consists in cumulating the successive signal elements of a group of signal elements and sending a single signal element of distinguishable character corresponding to the combination of signal elements in such group.

9. In the transmission of a train of signal elements, the method which consists in reducing the number of signal elements per second and correspondingly increasing the number of distinguishable characters for each signal element.

10. In the transmission of a train of signal elements, the method which consists in storing several successive signal elements and then sending a single signal element distinguishably determined in character by the combination of stored initial elements.

11. The method of signaling over a system in two parts on different commensurably related signal speeds with the signal elements of equal duration in the respective parts, which consists in converting the signal train between the two parts from the one signal speed to the other, at the same time making a corresponding change in the number of recognizable characters for each signal element.

12. In combination, a signal transmitting system having two parts, one part adapted for a certain signal speed and a certain number of possible distinguishable characters for each signal impulse, and the other part adapted for a different signal speed and a correspondingly different number of such characters, the signal impulses being of equal duration in each part, and means between the two parts to convert a signal train so adapted for

the one part into a corresponding signal train so adapted for the other part.

13. In combination, means to generate a train of signals of elements of equal duration at a certain signal speed and of a certain number of distinguishable characters per signal element, means to convert from such train of signals to another train of different signal speed and of elements of equal duration and correspondingly different number of distinguishable characters per signal element, means to transmit the converted signal train, and means at the receiving end to convert back to a signal train corresponding to the initial signal train.

14. In combination, means to produce a train of signal impulses, relays in which to store them, a distributor between said means and said relays, a line, and means to put a second set of impulses on said line, each corresponding to a set of separate impulses in the said relays, said distributor comprising means to determine the character of said impulses for the line according to the combination of impulses stored in the said relays.

15. In combination, means to produce a train of signal impulses, relays in which to store them, a distributor between said means and said relays, a line, means to put a second set of impulses on said line, each corresponding to a set of separate impulses in the said relays, said distributor comprising means to determine the character of said impulses for the line according to the combination of impulses stored in the said relays, storing relays at the receiving end and a distributor at the receiving end to determine the operation of said relays according to the character of the received signal impulses and distribute successive impulses to an indicator accordingly.

16. In combination, transmitting apparatus, a line and receiving apparatus, means between the transmitting apparatus and the line to convert a signal train of signal elements of equal duration from one signal speed to another train of signal elements of equal duration and from a corresponding number of distinguishable signal elements to another, and means between the line and the receiving apparatus to effect the inverse conversion whereby the ultimately received signal train will correspond to the initially sent signal train.

17. Means to convert a train of signal impulses of a certain number n per second and a certain number C of distinguishable characters for each impulse to a train in which these numbers are different subject approximately to the condition that C^n=constant.

In testimony whereof, I have signed my name to this specification this 6th day of January, 1928.

PIERRE MERTZ.