

Sept. 17, 1935.

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2,014,908

CHANNEL REPEATER FOR TELEGRAPH SYSTEMS

Filed Sept. 13, 1932

6 Sheets-Sheet 1

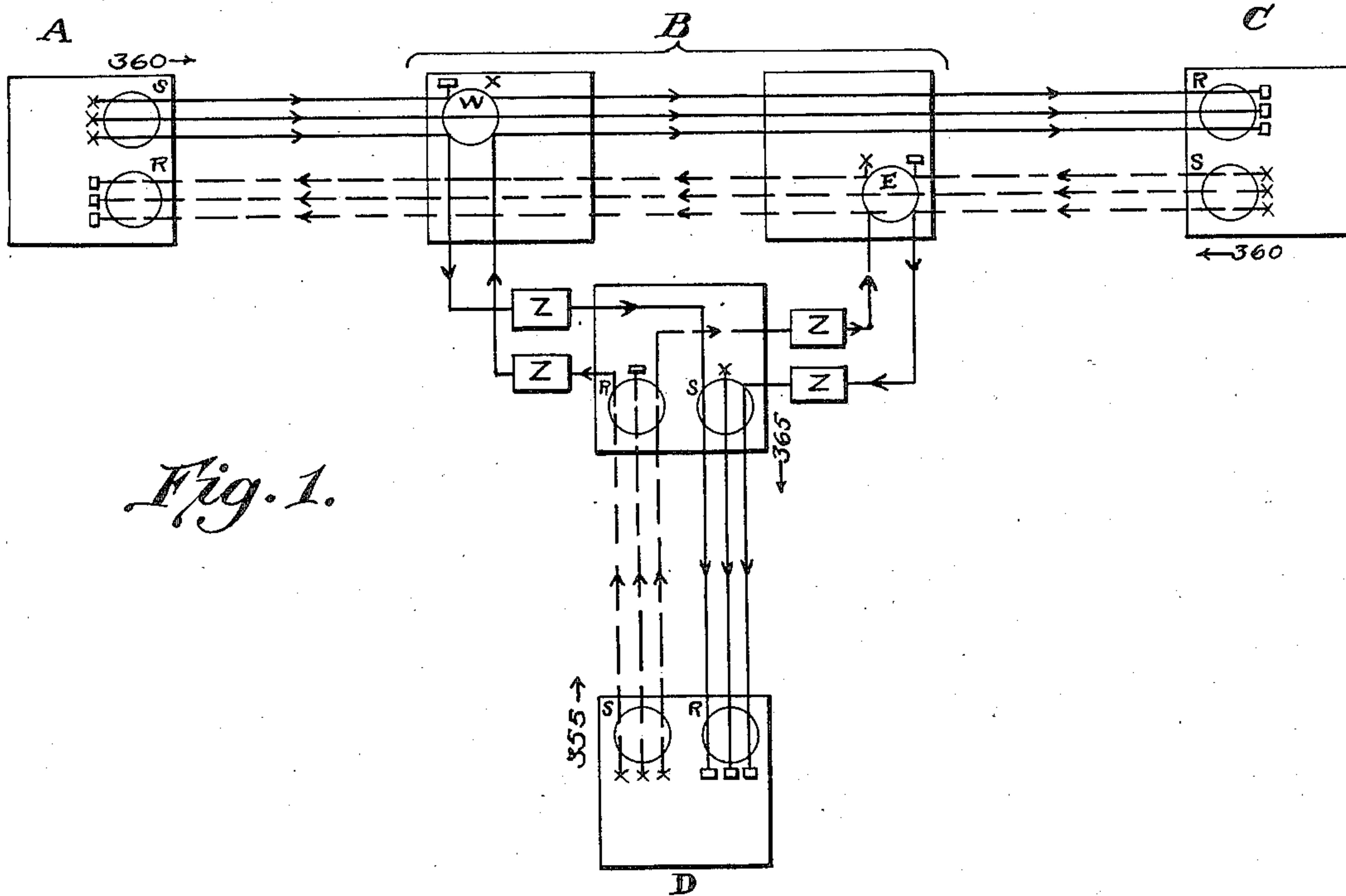


Fig. 1.

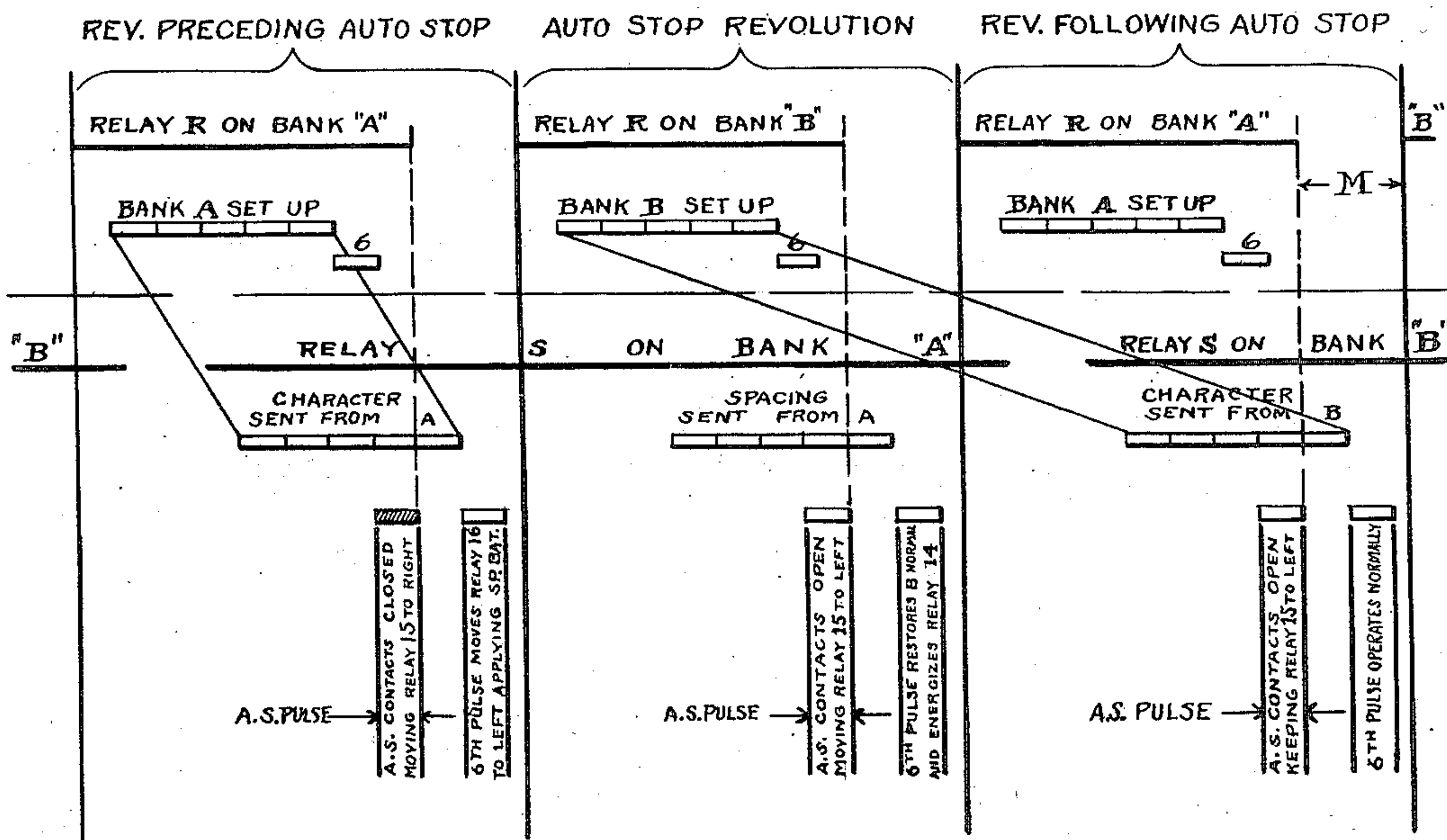


Fig. 3.

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6 Sheets-Sheet 2

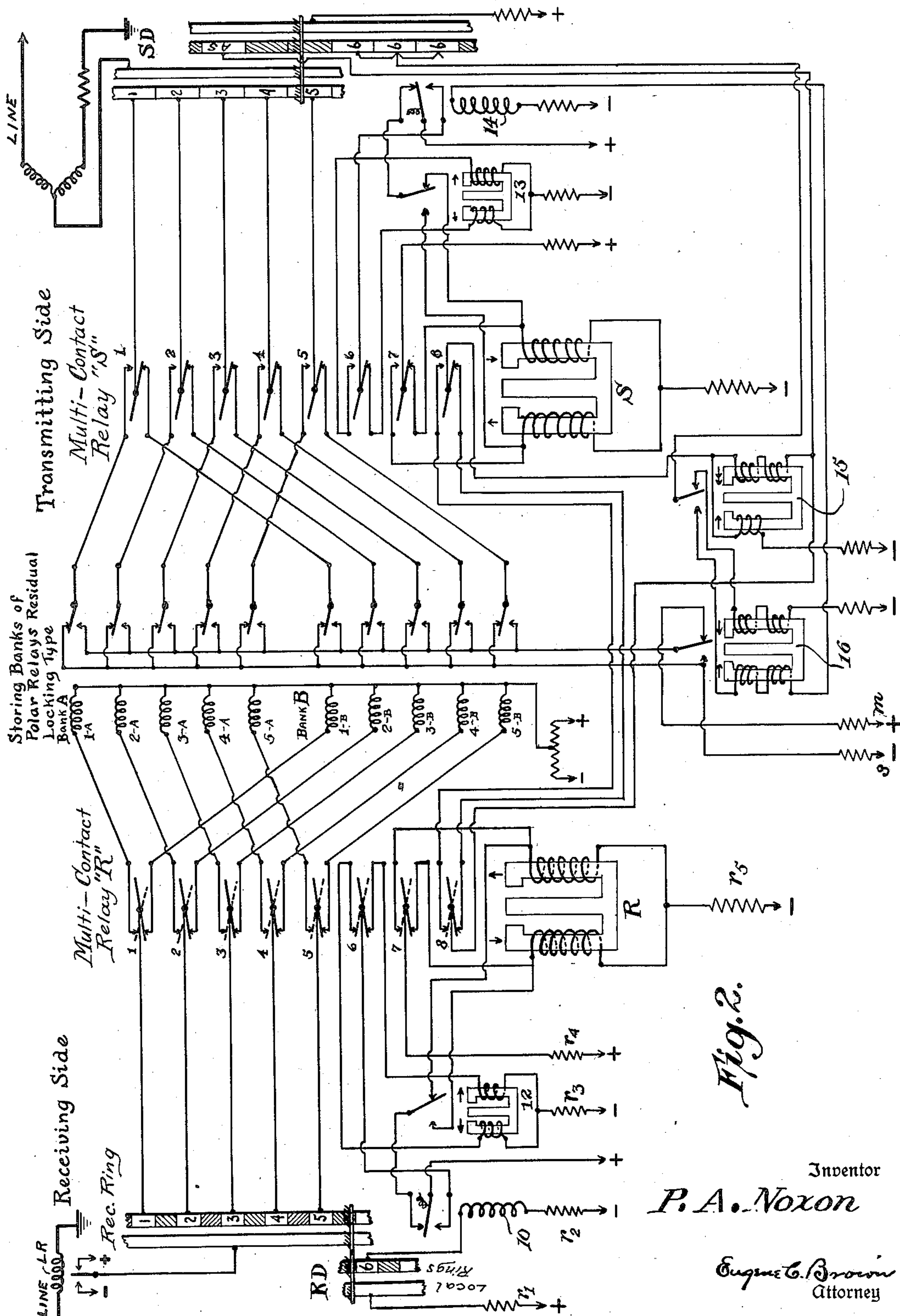


Fig. 2.

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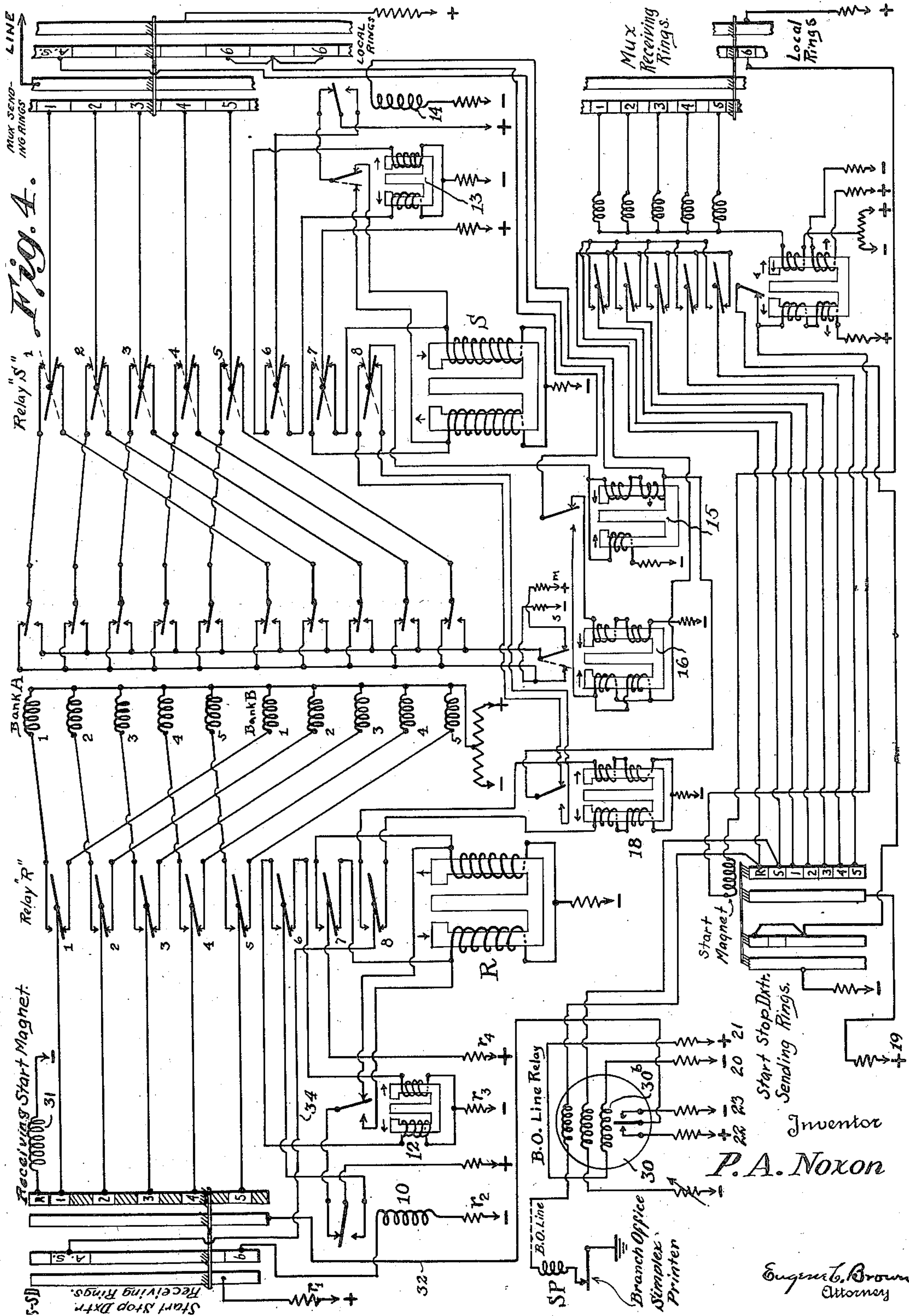
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CHANNEL REPEATER FOR TELEGRAPH SYSTEMS

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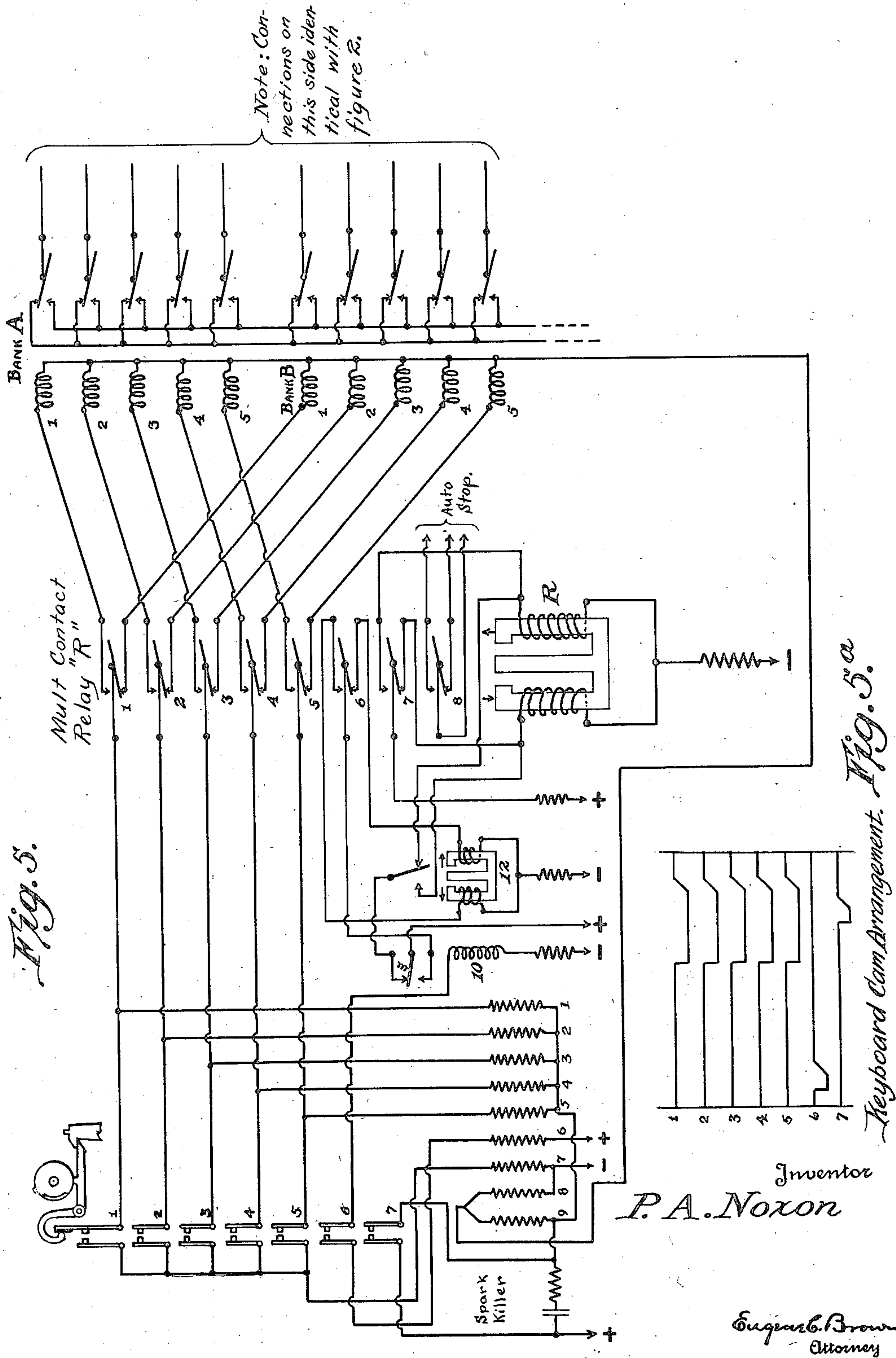
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CHANNEL REPEATER FOR TELEGRAPH SYSTEMS

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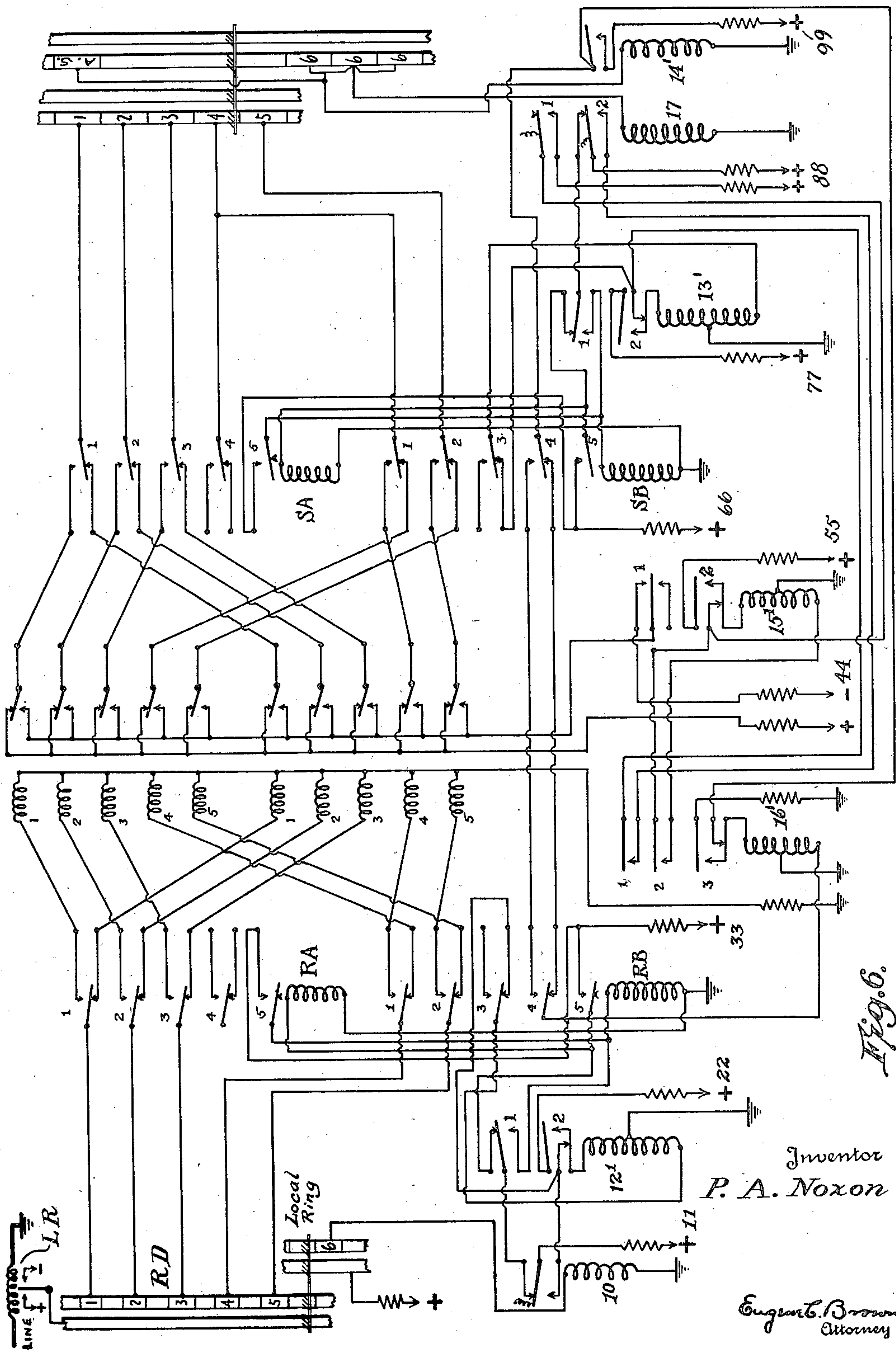
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CHANNEL REPEATER FOR TELEGRAPH SYSTEMS

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Sept. 17, 1935.

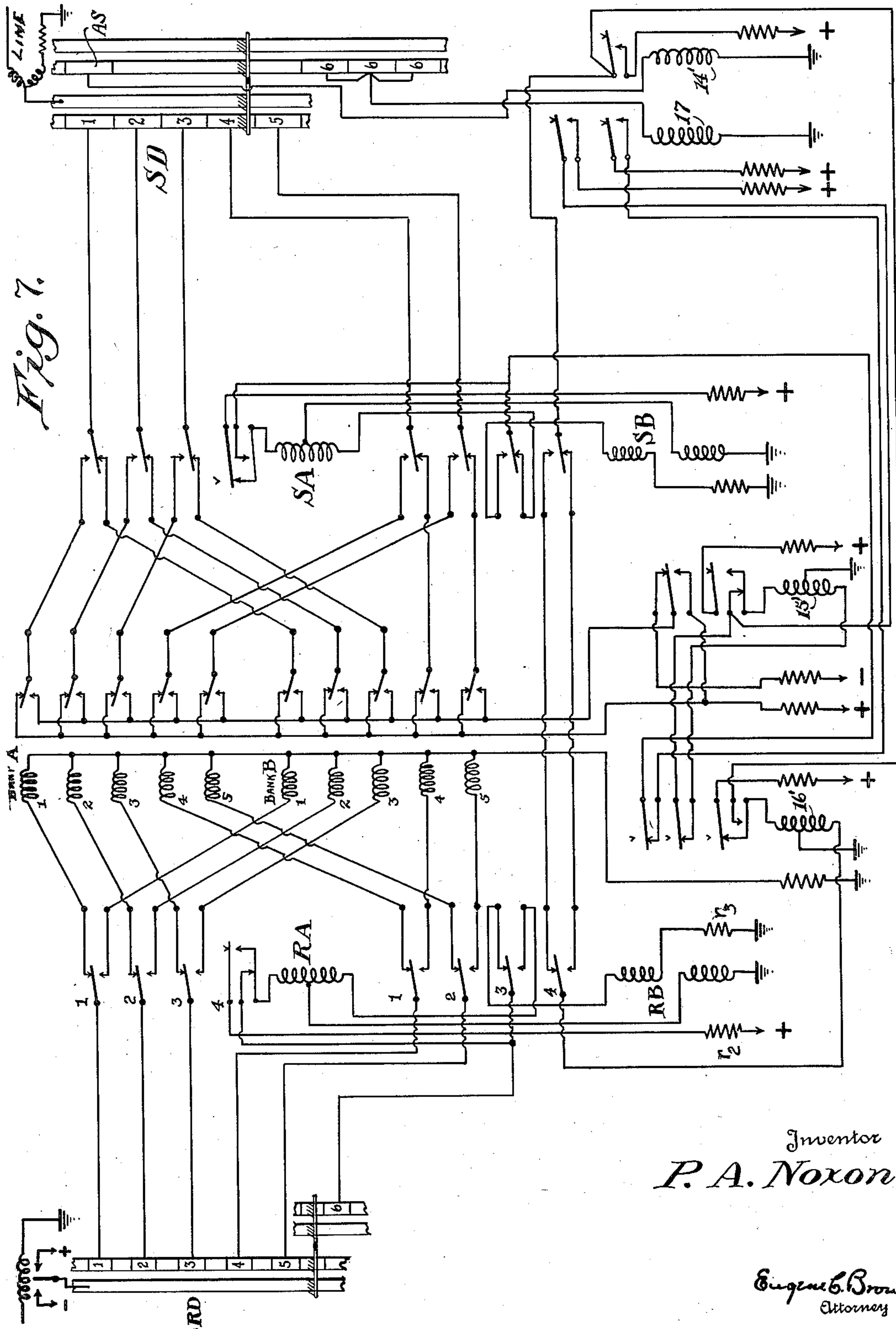
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CHANNEL REPEATER FOR TELEGRAPH SYSTEMS

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CHANNEL REPEATER FOR TELEGRAPH SYSTEMS

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Application September 13, 1932, Serial No. 633,001

8 Claims. (Cl. 178—71)

This invention relates to an apparatus for repeating signals from a channel or channels of a multiplex telegraph circuit or similar system into a channel or channels of another circuit without requiring the distributors of said circuits to be maintained in synchronism.

The object of the invention is to provide a repeating mechanism which will receive the code messages from the receiving distributor, store them momentarily and transfer them to a sending-on transmitting distributor which may operate at a different speed from that of the receiving distributor.

This apparatus is capable of providing a large variety of forked or series multiplex circuits, such as repeating through one or more channels of two existing multiplex circuits having terminals in the same office but on isolated distributor tables, repeating two independent double multiplex circuits into and out of a four-channel circuit, or providing a third leg on an existing series circuit. Since this apparatus is the equivalent of a storing transmitter of two-character storage, it is capable of application in any situation where a storing transmitter is used, (if the large storage capacity of the Wheeler and Dirkes storing transmitter, Patent 1,576,167, is not needed). Such applications include multiplex operation from a direct keyboard for "flash" service, and providing a multiplex extended channel utilizing simplex printers at the branch office, or working a multiplex channel from a simplex concentrator on the same basis.

In the following description I shall refer to the accompanying drawings, in which—

Figure 1 is a schematic diagram illustrating the application of my invention to a fork and series circuit of three, three-channel sections connecting four offices in a manner to supply each office with a channel to each of the other three.

Figure 2 is a diagram showing the circuits of my channel repeater.

Figure 3 is a diagrammatic illustration of the time relationships present in the channel repeater when repeating between two, two-channel distributors.

Figure 4 is a diagram showing the application of my channel repeater to an extended channel system, the receiving side of the repeater being set up by means of a start-stop distributor operated from a branch office over a simplex line.

Figure 5 is a diagram illustrating a circuit arrangement of my channel repeater arranged to permit free keyboard operation on a multiplex channel for "flash" service.

Figure 5^a is a developed view of the cam arrangement forming a part of the keyboard transmitter shown in Fig. 5.

Figure 6 is a diagram of the circuits of my repeater such as shown in Fig. 2 modified to substitute neutral relays for the polar relays in the transfer and auto stop circuits; and

Figure 7 is a further modification showing a simplification of the transfer circuits.

Figure 1 is a graphical illustration of the manner in which my channel repeater may be embodied in a fork and series circuit connecting four offices, A, B, C and D so that each office is provided with a channel to each of the other three. The channel repeaters are indicated at Z. It will be noted that with the speed relationship shown, each channel repeater repeats from a distributor at lower to one of higher speed. This obviously fundamental requirement must necessarily be met in any circuit arrangement of which the device is a part.

Figure 2 is a diagram of the circuits of my channel repeater. The storage capacity of two characters is provided by two banks of polar relays of the residual locking type, relays 1—A to 5—A comprising one bank, and relays 1—B to 5—B comprising the other. While the repeater as shown is arranged for a five unit code, it could be adapted to a code using a different number of units, by supplying a corresponding number of relays in each storing bank. The two storing banks are alternately connected to the multiplex receiving ring during succeeding revolutions through the medium of a multi-contact relay R. As indicated on the diagram, this relay has eight groups of contacts, five of which are used to transfer the storing banks. It has two independent coils arranged so that if one coil is energized, all the tongues engage the lower contacts and if the other coil is energized all the tongues move to the upper contacts. As shown in Figure 2, by means of a suitable circuit arrangement, alternate coils of the multi-contact relay are energized on succeeding revolutions of the receiving distributor RD, thus performing the transfer mentioned above, i. e., taking the first character of a message as #1, bank A would receive all the odd numbered characters in the message, while bank B would receive all the even numbered ones or vice versa.

On the sending side, the tongues of the storing banks are alternately connected to the sending segments of the sending distributor in the same manner as described above, by means of a second multi-contact relay S, which is controlled from

the sending distributor by a second transfer circuit arranged in a similar manner to that employed in the control of relay R. The characters which are being set up in the storing banks by the receiving elements are thus transmitted in the same order by the transmitting elements of the circuit.

Under ordinary conditions, the relays of bank B would be in the process of being set up at the approximate time that transmission was taking place from bank A, and vice versa. In other words, the maximum storage capacity of the device would be utilized, and the sending distributor SD would be a whole revolution behind the receiving distributor. Since the sending distributor is rotating at a somewhat higher speed, this large amount of overlap (i. e. angular lead of the receiving distributor with respect to the sending distributor) is gradually reduced until both distributors are connected to the same bank during a large part of the time. In this condition, the receiving brush might be in the act of setting up relay 5 of a bank at the instant that a pulse was being transmitted from relay 3 of the same bank.

Obviously, it would be disastrous to permit a closer approach than this, since we would eventually be attempting to send a pulse from a relay which had not yet had time to settle on its contact. At this time, therefore, a circuit comes into play which restores the overlap to its former maximum condition. This is accomplished by preventing relay S from transferring its contacts when the next sixth pulse arrives from the sending local ring. While this sixth pulse does not cause relay S to be operated, it actuates a relay which applies spacing line battery to the marking contacts of both banks, so that on the next revolution, while the receiving distributor proceeds to set up the opposite bank, the sending distributor sends a spacing block from the bank from which the previous character had been transmitted.

When the next sixth pulse arrives from the sending local ring, it restores marking battery and is permitted to transfer relay S to the bank just set up by the receiving distributor. This character is then transmitted on the next revolution, the receiving distributor at the same time setting up the opposite bank. The overlap is thus restored to maximum and transmission proceeds in a normal manner until the sending distributor has again caught up with the receiving distributor, when the process is repeated. The circuit which accomplishes the above function is evidently analogous to the well-known "auto stop" function incorporated in the multiplex auto control to stop the tape when the perforator is being operated at a rate lower than that of the circuit. Due to the more exacting requirements, however, it is necessary to employ a different circuit which will be taken up in detail later.

The operation of the channel repeater may be summarized as follows: Characters from the receiving distributor are set up alternately and continuously in the two relay banks. These characters are retransmitted alternately from the banks by the sending distributor, and this process continues until the greater speed of the sending distributor has cut down the overlap between reception and transmission to a minimum safe point. At this time the operation of the auto-stopping arrangement introduces a blank from one of the relay banks which readjusts the over-

lap to its maximum condition, when the normal operation is resumed.

In the foregoing discussion the channel repeater has been treated in a general way in order to outline the essential features of operation without involving details which are interesting mainly from the standpoint of design. In the following description the exact sequences of operation of the transfer and auto-stop circuits will be described, as well as the manner in which the marginal requirements are met in the latter.

Transfer circuits

In the general discussion above it was mentioned that a circuit was provided for actuating the multi-contact relays in such a manner that succeeding sixth pulses brought about the transfer of the connections from the receiving or sending segments from one bank to the other. The means for accomplishing this is incorporated in the transfer circuits of which there are two: one to actuate relay R and the other to actuate relay S. Referring to Fig. 2, the circuit associated with relay R, includes the sixth pulse segment on the local ring of the receiving distributor RD, a neutral relay 10, a polar relay of the residual locking type 12, contact groups #6 and #7 of multi-contact relay R, the coils of relay R, certain resistances, as required by the design of the relays involved, and a source of E. M. F.

Assume relay 10 to be deenergized, and relay 12 having its tongue resting on the right hand contact, being held in that position by virtue of residual magnetism previously established in its core. Current will flow from plus battery through the tongue of relay 10 to its upper or back contact, through the tongue and right hand contact of relay 12, where it finds a path through the right hand coil of relay R, to the opposite polarity. As the arrow indicates, energizing the right hand coil of relay R causes all of its tongues to engage their upper contacts, the position shown in dotted lines.

Now assume that the brush on the local ring moves into such a position as to connect the local solid ring with the sixth pulse segment. Relay 10 is energized, causing its tongue to be moved from the back to the front or lower contact. Although battery is now removed from the circuit connected to the back contact of relay 10, current continues to flow through the right hand coil of relay R by virtue of the circuit through resistance r_4 , the tongue and upper contact of group 7 of relay R, and the right hand coil of relay R, thus keeping relay R locked in its previous position.

Still assuming relay 10 to be energized, a circuit is provided through the tongue and upper contact of contact group 6 of relay R through the left hand coil of relay 12, which, as the arrow indicates, moves its tongue to the left and establishes a residual magnetism in that direction in its core.

Now when the local brush passes off segment #6, relay 10 is deenergized and its tongue moves to the upper or back contact. A circuit is now provided from the tongue of relay 10 through its back contact, through the tongue and left hand contact of relay 12, and energizing the left hand coil of relay R.

Since the value of the locking current controlled by resistance r_4 is made to be less than the current now flowing through the left hand coil of relay R, the left hand coil is effective, and moves the tongues to engage their lower contacts, the position indicated in solid lines.

In a similar manner it can be shown that the next sixth pulse will first cause relay 12 to be thrown to the right, then, as relay 10 is released, the right hand coil of relay R will become energized, restoring relay R to its original position. Successive sixth pulses, thus, alternate the position of the tongues of relay R.

A similar transfer circuit is associated with relay S. It includes the coils of multi-contact polar relay S, polar relay 13 and neutral relay 14 and the local ring sixth pulse segment of the transmitting or sending-on distributor SD. While relay 14 corresponds to relay 10 in the circuit described above, it will be noted that it is not connected directly to the sixth pulse segment as was relay 10. The reason for this will be developed in connection with the description of the "auto stop" circuit.

Auto stop function

The "auto stop" circuit includes polar relays 15 and 16, (both of the residual locking type), contact groups 8 of relays R and S, and a special auto stop segment AS located on the sending local ring. The sending sixth pulse segment, as well as the coil of relay 14 may also be considered a part of the "auto stop" system. Referring to Figure 2, it will be noticed that the contacts of group 8 on relay R are connected to the corresponding contacts of group 8 on relay S.

If relays R and S are both on the same corresponding contact (i. e. both distributors are connected to the same relay bank), the tongue of contact group 8 of relay R, is connected to the corresponding tongue of relay S through the medium of the strapping connection mentioned above. Hence the right hand coils of relay 15 are shorted out whenever the two relays R and S are energized in the same direction, or whenever the two distributors are connected to the same bank of relays. Bearing this in mind, it is evident that as the local brush of distributor SD traverses the auto stop segment AS, the resulting pulse of current will throw relay 15 to the right or left, depending on whether relays R and S are resting on the same or on opposite sides at the time (since shorting the right hand coils makes the left hand coil effective in throwing the tongue of relay 15 to the right, these coils when not shorted are together being equal to twice the left hand coil and oppositely poled, hence enabling them to throw the tongue of relay 15 to the left). It is also evident from the figure, that relay 16 is operated by the sixth pulse, the direction of operation being dependent on the position of relay 15. Furthermore, when the left hand coils of relay 16 are energized, the same pulse also passes through the coils of relay 14, enabling it to actuate the transfer circuit, but a pulse through the right hand coils of relay 16 has no effect on relay 14, since it finds a path through a separate return.

We may now trace the sequence of operation of the "auto stop" circuit during the revolution just previous to, during and following an auto stop function. In order to show the relationship between various events occurring during these three revolutions, it may be well to make use of a time diagram. Fig. 3 illustrates the time relationships present in the channel repeater when repeating between two two-channel distributors. By drawing an imaginary vertical line through the diagram at any point, we can note what is taking place in any portion of the device at that instant, and by moving this imaginary line from left to

right we can obtain a complete picture of the events occurring in these three revolutions. Referring to Figure 3, it may be seen that the sending distributor SD has approached the receiving distributor so closely that on the revolution preceding the operation of the auto stop, the sending brush is about to transmit #1 pulse at the instant that the receiving brush is setting up #3. It will also be noticed that during the whole time of transit of the sending local brush over the auto stop segment, relays R and S have been both resting on the same relay bank (bank A) and therefore remembering the functioning of contact groups 8 on relays R and S, it is evident that the right hand coils of relay 15 have been shorted for the entire period. Relay 15 then is thrown to the right by the auto stop pulse, being held in that position after the pulse has passed, by virtue of the residual magnetism established in its core.

Now when the local brush of distributor SD traverses the sixth pulse segment, current flows through the tongue and right hand contact of relay 15, through the right hand coil of relay 16, causing its tongue to be thrown to the left, thus applying spacing battery to the marking contacts of both banks. After the passage of the sixth pulse, relay 16 is held on its left hand contact, since it also locks by means of residual magnetism.

During the following or auto stop revolution, the receiving side of the repeater functions in a normal manner. Relay R had been transferred to the opposite bank (B), and the receiving brush proceeds to set up a character thereon when the segments of RD are traversed. However, since relay 14, controlling the sending transfer circuit, was not energized, (relay 15 being on its right hand contact), relay S remains in its former position (on bank A) so that when the sending brush traverses the sending segments, it sends from the same bank as on the previous revolution, but since both marking and spacing contacts of both banks have spacing battery applied to them, due to the operation of relay 16, the sending brush encounters nothing but spacing battery, and a spacing block signal is transmitted.

During the time the local brush of sending distributor SD is passing over the auto stop segment on this revolution, it will be observed that while relay S is on the A side, relay R is on the B side. Consequently, current flows through both right hand coils of relay 15 in addition to the left hand coil, which, as explained before, throws it to the left where it remains locked by the residual magnetism. Now when the sending local brush of SD subsequently passes over the sixth pulse segment, current flows through the left hand coils of relay 16, throwing it to the right, where it remains by virtue of the residual magnetism as before. This pulse of current finds its return through the coil of relay 14, causing it to become energized and thus bring about the transfer of relay S to the opposite (B) relay bank, as explained above under "transfer circuits". The operation of relay 16 restored marking battery to the contacts of the relay banks, permitting the sending brush of SD to send, on the following revolution, the character which had been set up on bank B during the auto stop revolution. During the revolution following the auto stop revolution, since the operation of the receiving side has not been impeded, bank A is connected to the receiving segments of RD and is set up. Also during this revolution, and on subsequent revolutions, the right hand coils of relay

15 are effective, keeping relay 15 on its left hand contact (since relays R and S are always on opposite banks). Furthermore, each succeeding sixth pulse passes through the left hand coils of relay 5 16, keeping it to the right, as well as energizing relay 14, which controls the transfer circuit. Operation from this point proceeds in a normal manner until the sending distributor, due to the difference in speed, has again reached the condition first described, when the auto stop function is repeated. 10

It may be of interest to note that while I have considered the spacing block signal to have been transmitted from bank A, it may be transmitted 15 from bank B, the sequence of operations being the same, except that the positions of bank A and bank B are interchanged in Figure 3 and in the above discussion.

The auto stop circuit incorporated in the channel repeater differs from former auto stop circuits employing an auto stop pulse, as represented by the systems used with the storing transmitter on multiplex channels and on the simplex extended channel circuits, in that the auto stop 25 pulse is a purely preparatory function. That is, the phase relationship between the receiving and sending elements at the time of the auto stop pulse causes a selection to be set up so that the succeeding sixth pulse may perform the actual 30 function that is required, whereas in said prior arrangements the auto stop pulse functions to turn over the line battery and at the same time prevents the sixth pulse from stepping.

Auto stop margin

35 Up to this point I have not considered specifically what margins are required, nor how they are obtained. It may therefore be advisable to discuss this feature briefly.

40 It has been mentioned that a certain amount of overlap must be maintained between reception and transmission in order not to send pulses from relays which have not yet settled on their contacts. In the system under discussion, this relationship at the time of minimum overlap just 45 previous to the auto stop revolution can be fixed by selecting a suitable location for the auto stop segment on the sending local ring.

Referring to Figure 3, it is evident that the 50 relationship of the two distributors at the moment of auto stop function is determined by the alignment (in time) of the instant that relay R breaks contact (on either side) with the instant when the sending local brush is about to leave 55 the auto stop segment. (Note: If relay R breaks away from its contacts during the earlier portion of the auto stop pulse, the latter portion finds the right hand coil of relay 15 unshorted, and hence reverses the flux established by the left 60 hand coil during the earlier part of the pulse when the right hand coils were shorted. This means that the trailing edge of the segment is effective.)

Bearing this in mind, it is evident from the 65 diagram that moving the auto stop segment farther away from the sixth pulse segment would increase the overlap between setting up and retransmission at the time of auto stop by a corresponding amount. While the instant that relay 70 R breaks contact changes with speed, it is possible to so fix the location of the auto stop segment as to provide sufficient overlap over the entire range of speeds in use.

75 There is another requirement fundamental to any system of this character which has not been

mentioned. With a small difference in speed, the actual phase relationship of the two distributors is practically the same after an auto stop as before, hence the segmental relationship which brought about an auto stop is still present. For 5 this reason there will be a tendency toward repeated auto stopping unless the system incorporates means of differentiating between the conditions immediately preceding and immediately 10 following an auto stop. The manner in which the circuit accomplishes this may be realized by referring to the revolution following an auto stop as indicated on Figure 3. It is evident that during the entire auto stop pulse the auto stop contacts 8 are open, since relays R and S are resting 15 on opposite contacts. Moreover, it would be possible for the sending distributor to actually drift in the reverse direction (displacement of the sending functions to the right on Figure 3) through the angular distance M (practically the travel 20 time of relay R) before the auto stop pulse met a closed auto stop contact, and repeated auto stopping occurred. This may be realized by referring to the diagram, since the tongues of group 8 of relay R are in mid-air during this period, 25 evidently producing an open auto stop.

The means for differentiating between the pre-and-post auto stop conditions is thus evidently provided by the following features:

- (a) Auto stopping on a closed contact. 30
- (b) Providing travel time in relay R.

Simplex extended channel

I have stated above that since the channel repeater is the equivalent of a storing transmitter 35 with a storage capacity of two characters, it can be used in any situation involving a storing transmitter, provided the relatively large storage capacity of the latter is not an essential feature.

A storing transmitter is utilized in the simplex extended channel system to permit the 40 free operation of the simplex keyboard at the branch office. An extended channel system of this type is shown in my application Ser. No. 581,946. In that system the large storage capacity of the storing transmitter is used to permit multiplex operation at speeds lower than the simplex keyboard, a stop warning signal being provided to warn the branch office to stop transmission when the storing transmitter is 50 completely filled. If we are willing to fix the multiplex speed at such a rate that the simplex printer can never send at a faster rate than the multiplex, the large storage capacity of the storing transmitter is unnecessary, just enough 55 capacity to permit the free operation of the simplex keyboard being all that is required, and this the channel repeater can supply. However, we must still be able to transmit from the multiplex into the simplex printer at the branch 60 office, hence transmission in this direction must not be faster than the printer can handle. In order to fully meet these conditions, the multiplex speed is practically limited to the range of 392 to 400 R. P. M. On the other hand if we are 65 willing to alter the speed of the simplex printer instead of the multiplex, the system could be made to function at practically any speed desired.

Figure 4 is a diagram showing the circuits of 70 an extended channel system based on the channel repeater. It will be noticed that the receiving side of the channel repeater is set up by means of a start-stop distributor S—SD, the operation being exactly similar to the multiplex 75

application except for one feature. In the multiplex-to-multiplex application of the channel repeater above described, I do not at any time interrupt the regular sequence of operations of the receiving elements of the circuit. In setting up the channel repeater from a start-stop distributor, however, the sequence of operations is in general interrupted between every letter or character, coming to rest completely when the sending operator pauses. If we attempted to utilize the channel repeater without modification in this situation, it will be evident that relay S would come to rest on the relay bank connected to the start-stop face plate of relay R, and the sending brush would continue to send spacing from this bank (assuming relay R at rest). Now if we attempted to set up a letter from the start-stop distributor, it would fall on the bank being employed to furnish spacing blocks to the sending distributor, and since marking battery would be applied to the banks at the time relay S was transferred to the opposite bank, it is evident that the first character would never be transmitted.

To avoid this condition, another polar relay of the residual locking type is added to the repeater (relay 18), the tongue and contacts of which replace contact group 8 of relay R in the auto stop circuit in the arrangement of Fig. 2. Group 8 is then available for the control of relay 18, but the operation of relay 18 is timed by means of a local segment on the start-stop distributor. This segment is so located that it moves the tongue of relay 18 to the contact corresponding to the side on which relay R is resting, only after the receiving brush of the start-stop distributor is actually in motion in the act of setting up a character. This means that as the start-stop distributor comes to rest, while relay R has been transferred to the opposite bank by the sixth pulse, relay S will come to rest on the bank from which the character has been transmitted due to the control exerted by relay 18 on the auto-stop circuit. In the state of rest, then, relays R and S rest on opposite sides, and the first character is not dropped out.

The following is a detailed explanation of the sequence of operations which is carried out in transmitting a character from the branch office into the multiplex circuit in the system shown on Figure 4.

First let us assume a state of rest, that is, steady marking potential being received from the branch office by virtue of the fact that the simplex keyboard is not being operated, hence holding the branch office line closed. Current flows from plus battery 19 through the "rest" segment of the start-stop distributor sending ring through the line coil of the branch office line relay 30, (holding it to the right or marking side) to the branch office, where it finds a ground return.

It is evident that the receiving start magnet 31 of the start-stop distributor is not energized, since minus polarity from battery 23 is applied to its coil through the tongue of relay 30, conductor 32 and the receiving rest segment, the opposite terminal of the coil 31 being also connected to minus battery. Hence the start-stop distributor is not set in motion and the brush remains on the rest segment R.

Let us assume that relay R has the start-stop distributor receiving segments connected to storing bank B (as shown on the diagram). A study of the diagram will make it obvious that the

tongue of relay 18 is in the position shown, i. e., to the right, since it must have been set in that position on the revolution during which the start-stop distributor receiving brushes come to rest, (as previously described). For the sake of simplicity, let us also assume the sending function of the channel repeater to be at rest. At this time relay S is resting on bank A, hence relay 15 has its right hand coils shorted (via the circuit through the tongue and right hand contact of relay 18 and the upper contact and tongue of group 8 relay S), and hence successive auto stop pulses from the A. S. segment of the multiplex local ring serve to keep the tongue of relay 15 to the right. Successive sixth pulses from the multiplex local ring pass through the tongue and right hand contact of relay 15, through the right hand coils of relay 16, keeping its tongue to the left and applying spacing battery to the marking contacts of both banks. Since these sixth pulses do not pass through the coil of relay 14, the transfer circuit is not operated, and hence relay S remains in its assumed position, i. e. having bank A connected to the multiplex sending rings. Since spacing battery is applied to both marking and spacing contacts of both banks (by virtue of the position of relay 16) on each revolution of the multiplex distributor, the sending brush encounters nothing but spacing battery, and spacing block signals are transmitted (from bank A.)

Let us now assume that the branch office operator depresses a key on the keyboard of her simplex printer SP. The first signal received from the branch office is a start signal, which is spacing, (in the system shown an open condition of the branch office line). Since no current flows through the line coil of the branch office line relay 30, the bias winding 30^b assumes control and throws the tongue of the branch office relay to the left. Current now flows from plus battery 22 through the tongue of the branch office line relay, through conductor 32 and the solid receiving ring of the start-stop distributor, through segment R and the receiving start magnet, causing it to be energized, and thus releasing the receiving brushes.

At the approximate time that #1 pulse is being received from the branch office, the local brush of the start-stop distributor S—SD applies plus battery to the auto stop segment on the start-stop distributor receiving local ring. Current flows through conductor 34, the tongue and lower contact of group 8 of relay R, and through the left hand coil of relay 18, to minus battery, thereby moving the tongue of relay 18 to its left hand contact.

Let us leave the start-stop distributor receiving brush in the process of setting up bank B as it traverses segments 1 to 5, and consider the events occurring on the sending side at the right of the figure. We may assume the multiplex local brush to have just started to move across the A. S. segment as relay 18 was operated. Since the operation of relay 18 lifted the short circuit from the right hand coil of relay 15, the A. S. pulse thus throws its tongue to the left, thereby providing a path through the left hand coil of relay 16 and through the coil of relay 14 for the succeeding sixth pulse, which is thus enabled to operate relay 16, restoring marking battery to the sending contacts while relay 14, brings about the transfer of relay S to bank B in the manner previously described.

By this time the brush of start-stop distributor

S—SD has completed the setting up of bank B and after the sixth pulse from the start-stop distributor local ring has brought about the transfer of relay R to bank A, in the manner previously described, the start-stop distributor brushes come to rest on segment R, if only one character had been transmitted.

The multiplex brushes continue to revolve, and on the next revolution the character is transmitted from bank B. Since the tongue of relay 18 is still to the left, however, the A. S. pulse on this revolution finds the right hand coil of relay 15 shorted (circuit via the tongue and left hand contact of relay 16 and lower contact and tongue of group 8 relay S), hence throwing the tongue of relay 15 to the right. The sixth pulse finds no path through relay 14, and hence cannot bring about the transfer of relay S. It does, however, throw the tongue of relay 16 to the left thus applying spacing battery to the sending contacts.

We have again reached a state of rest. The multiplex sending brushes continue to send spacing blanks, and the transfer circuits are not operated. Relay R is now, however, resting on bank A, while relay S is on bank B, which is opposite to the condition from which we started.

It is obvious that the next character transmitted will cause the same sequence of operations to be carried out except that the character will be stored in and transmitted from bank A.

If the receiving start-stop distributor is operated continuously instead of intermittently as described, the operation of the system is practically identical with the multiplex to multiplex application, blanks being inserted in the transmission periodically to compensate for the necessary difference in speed and to maintain the necessary overlap between setting up and retransmission.

While the complete system shown on the diagram is arranged as a duplex-half repeater for single line operation on the simplex side, it could equally well provide full duplex operation by means of a duplexed line, or leg operation, by means of two line wires on the simplex side, as will be evident to engineers.

The channel repeater can also be used to permit free keyboard operation on a multiplex channel for "flash" service.

The manner in which this may be accomplished may be seen by referring to Figure 5. The keyboard is similar to the keyboard used in connection with the storing transmitter, and is of the well-known type shown in patent to Krum 1,595,472 and Long 1,800,190, except that the contact arrangement is necessarily different. The rotating cams which engage the contacts to close the circuits are arranged as shown in developed form of Fig. 5a. Since the contacts are simple make and break contacts, in order to set up on polar relays, it is necessary to employ a potentiometer arrangement. To show how this network functions, let us assume that we wish to set up the letter Y in bank A. Assuming relay R to be resting on the B side, as the keyboard cam-shaft rotates, the first contact which closes is the "sixth" pulse or contact, this energizes relay 10, and as contact 6 opens on further rotation of the shaft, relay R moves to the A side by reason of the operation of the transfer circuit, as previously described. Now contacts #1, #3 and #5 are closed by the cams, having been selected by the "Y" key of the keyboard, thus preparing the network to set up a "Y" combination on the bank

of relays. As contact #7 is closed by the cam, it supplies plus battery to the entire network, and current flows from the midpoint of the potentiometer, formed by resistance #8 and #9, through the coils of the relays connected to contacts #1, #3 and #5, and through potentiometer resistance #7 to minus battery.

Current also flows from plus battery through potentiometer resistances #2 and #4, and the coils of relays #2 and #4 to the midpoint of resistances #8 and #9. Since this direction is opposite to that flowing through relays 1, 3 and 5, a "y" selection is evidently set up in the relays of bank A. It is apparent that resistances #1, #3 and #5 constitute a drain on resistance #7, thus reducing the voltage available for setting up the relays. However, it is possible to so adjust the values of the various resistances in the circuit that substantially equal current values are obtained for both marking and spacing pulses.

Following the setting up of the selection in the A bank of relays, contact #7 opens, thus removing battery from the network, after which contacts 1, 3 and 5 open, and the cam shaft comes to rest.

It will be remembered that in setting up the channel repeater from a start-stop distributor, it was necessary to set up on a bank of relays not connected to the sending distributor when starting from a state of rest. Evidently the same requirement must be met in setting up from a keyboard. In this application, however, instead of supplying an extra relay to control the auto stop functions, the requirement is taken care of by first transferring relay R before transmitting the selection to the bank of relays.

It is sometimes advantageous to employ neutral relays instead of polar relays. In Fig. 6 I have shown how the arrangement of Fig. 2 may be modified for this purpose by substituting two neutral relays respectively for relays R and S. Relay R has been replaced by relays RA and RB. Similarly relay S has been replaced by relays SA and SB. The polar relays employed in the former system for control purposes have also been replaced by neutral relays; that is, polar relays 12, 13, 15 and 16 have been replaced respectively by neutral relays 12', 13', 15' and 16'. Since the general features of operation are identical with the former system, only those functions which are specifically different will be considered in this description.

Transfer circuits

In this modification, the receiving transfer circuit consists of relays 10, 12', RA and RB. It will be noticed that contact group 5 of relay RA (when this relay is deenergized), applies plus battery to the coil of relay RB. Similarly, contact group 5 of relay RB (when that relay is deenergized) applies plus battery to the coil of relay RA. Thus when either of these relays is deenergized, the other is locked, and conversely, if either of the relays is energized, it unlocks the other, since the locking contact group is then opened.

Let us now consider the sequence of operations of the receiving transfer circuit. Assume relay RA to be energized, thus holding its contact group 5 open and allowing relay RB to rest on its back contacts. Relays 10 and 12' are likewise not energized and hence are resting on their back contacts. It will be noted that current from battery 11 flows through the tongue and back contact of relay 10 through the tongue and back contact of group 1, relay 12', through the coil of relay RA to ground, maintaining relay RA locked. Now

when the local distributor brush moves onto the sixth pulse segment, relay 10 is energized, moving its tongue to front contact and thereby removes battery 11 from the coil of relay RA. But this relay continues to be energized by current battery 33 through the back contact and tongue of relay RB.

When the tongue of relay 10 moves to its front contact, current flows from battery 11 to the normal of group 2 of relay 12', and through upper half of the coil of that relay. Since group 3 of relay RB is at this time open, the lower half of the coil of relay 12' is not effective; hence relay 12' is energized and its tongue begins to move. Before the normal connection is broken, however, the tongue of group 2 of relay 12', establishes a connection with the front contact, which supplies locking current from battery 22 through the upper half of the coil relay 12', holding it in energized position. Since the tongue of group 1 of relay 12' has now been moved from the back to the front contact, when the local receiving brush passes off the sixth pulse segment, allowing relay 10 to be deenergized, current flows through the tongue of relay 10 through the tongue and front contact of group 1 of relay 12' and through the coil of relay RB, causing it to be energized, thus breaking the circuit through group 5 of that relay and allowing relay RA to be released.

When the receiving local brush again rotates into such a position as to apply battery to the receiving sixth pulse segment, relay 10 is again energized and its tongue again moves from back to front contact. While this breaks the former path of the current through the coil of relay RB, the relay is still energized by virtue of the lock established by the previous closing of contact group 5 of relay RA. Since contact group 3 of relay RB is now closed, operation of relay 10 applies current from battery 11 through its front contact through said group 3 to the lower half of the coil of relay 12'. Since the two halves of the coil of relay 12' are opposite in effect, this neutralizes the flux maintained by the locking circuit and allows relay 12' to be deenergized. Before the tongue breaks contact, however, the normal connection is reestablished to the upper half of the coil of relay 12', maintaining the differential condition and allowing relay 12' to remain deenergized after the subsequent release of relay 10.

It will be noticed that when relay 10 is deenergized, current can flow through its tongue and back contact, through the tongue and back contact of group 1 of relay 12' and through the coil of relay RA, causing it to be energized. This breaks the lock established by contact group 5 of relay RA, and hence relay RB is deenergized. Since this is the condition from which we started, it is evident that succeeding sixth pulses cause the alternate operation of relays RA and RB, thus effecting the transfer of the receiving segments between the two storing polar banks, 1A—5A and 1B—5B.

The sending transfer circuit consists of relays SA, SB, 13' and 17. It operates in exactly the same manner to effect the transfer of the sending segments between the tongues of the storing banks on alternate revolutions. It will be noticed that while relay 17 corresponds to relay 10 in the receiving transfer circuit, it has an additional contact. Also, it will be noticed that the front contact of group 2 of relay 17, instead of going directly to the normal of group 2 of relay 13' is connected to it through a contact on relay 16'. These differences are for the purpose of auto stop con-

trol and will be discussed in connection with the auto stop circuit.

Auto stop circuit

While the auto stop circuit is similar to that covered in the former description, the exact sequence of operations is of necessity different, due to the fact that neutral relays are employed in place of the polar relays employed in the other arrangement. The auto stop circuit includes relays 16', 15', 14' and the auto stop segment (AS). It should be noted that relay 14' is not an essential part of the system, since the function performed by its tongue and contact could equally well be accomplished by the local brush and auto stop segment. It is included for the purpose of permitting the auto stop circuit to be energized by the same side of the local battery as that supplying the receiving functions, without requiring that the two distributor tables be connected to the same local generator. For the same reason the added contact on relay 17 is employed to furnish a sixth pulse to the auto stop circuits, instead of obtaining it directly from the sending sixth pulse segment.

The sequence of operations of the auto stop circuit will now be taken up. As explained in the former description, during normal operation of the repeater the receiving segments would be connected to storing bank A at the time the transmission was taking place from bank B, or vice versa. This means that as the sending local brush passes over the auto stop segment and energizes relay 14', the tongues of groups 4 of relays RB and SB would be in opposite positions and no circuit would be established from the tongue of relay 14' to the lower coil of relay 16'. At the time relay 14' is energized by the auto stop pulse, however, battery is supplied from the tongue of relay 14' to the normal of group 3 of relay 16' (assuming relay 16' to be deenergized) which, since it passes through only the upper half of coil of relay 16', causes it to be energized. Before the normal connection is broken, the tongue of group 3 supplies battery to the coil, permitting relay 16' to be energized after the release of relay 14'.

When the sending local brush moves into such a position as to apply battery to the sending sixth pulse segment, energizing relay 17, two functions are performed: (1) Plus battery is supplied through the tongue and front contact of group 2 of relay 17 through the tongue and front contact of group 1 of relay 16' to either the normal of group 2 of relay 13' or the lower half of the coil of that relay, effecting its operation in the sending transfer circuit, as before described. (2) Plus battery is supplied through the operation of group 1, relay 17, to the lower half of the coil of relay 15', through the tongue and contact of group 2, relay 15', which, assuming relay 15' to have been energized, neutralizes the flux established in its core by the locking circuit and permitting it to be deenergized. Since the normal connection is established in relay 15' before the tongue of group 2 breaks the lock, the differential condition is maintained and relay 15' remains deenergized after removal of battery by the release of relay 17.

Since the release of relay 15' permits the tongue of group 1 of that relay to rest on its back contact, marking line battery is supplied to the marking contacts of both storing banks, permitting the transmission of a character on the subsequent revolution. For normal operation then, relay 16' 75

remains locked in its energized position and relay 15' is maintained in its deenergized position, operation of relays 17 and 14' on subsequent revolutions making no further change in the positions which relays 16' and 15' occupy. Now assume the receiving brush to encroach on the sending brush (as outlined in the former description) to such a position that during the time that the auto stop pulse holds relay 14' closed, the tongues of groups 4 of relays RB and SB are in the same corresponding position. Battery now flows from the tongue of relay 14' through the tongues and contacts of groups 4, relays RB and SB, through the lower half of the coil of relay 16', neutralizing the flux being maintained by its locking circuit, and allowing it to become deenergized. As explained before in connection with similar relays, the normal connection is reestablished before the locking tongue breaks contact, maintaining the differential condition of the coil and allowing relay 16' to remain deenergized after the release of relay 14'.

Now, when the sending local brush subsequently passes on to the sixth pulse segment and energizes relay 17, current flows through the tongue and contact of group 1 of relay 17 through the normal of group 2, relay 15', through the upper half of the coil of that relay. Since contact group 2 of relay 16' is now open, no current flows through the lower half of the coil of relay 15', hence relay 15' is not now differential and becomes energized, remaining locked, as before described in connection with similar relays. The operation of relay 15' removes marking battery from marking contacts of the two storing banks and supplies spacing to these contacts, in anticipation of the spacing block to be sent on the subsequent revolution.

Since group 1 of relay 16' is now open, no pulse is received from the front contact of group 2, relay 17, by relay 13'; hence operation of the sending transfer circuit is not effected and relays SA and SB remain in their former position. Now, when the sending brush subsequently traverses the sending segments, a spacing block signal is transmitted from the same storing bank from which the previous character had been sent. Since, however, the receiving transfer circuit has not been interrupted, relay RB has meanwhile been moved to the opposite position. When the sending local brush passes over the auto stop segment and energizes relay 14', no circuit is established from the tongue of relay 14' to the lower half of the coil of relay 16' by virtue of the operation of the tongue of group 4 of relay RB. Battery is, however, supplied from the tongue of relay 14' to the normal of group 3 of relay 16', causing it to be energized and locked, as before described. When the sending local brush passes over the sixth pulse segment and energizes relay 17, relay 15' is released, and operation of the transfer circuit is effected as first described. Operation from this point proceeds in a normal manner until reduction of overlap caused by the creep between two multiplex distributors brings about the conditions for auto stop, when the above functions are repeated.

The requirements for obtaining margin in this system are the same as those covered in the previous description of Fig. 2, and the methods of obtaining them are identical with the system covered in that description.

In Fig. 7 I have illustrated a further modification in which the transfer circuit is simplified by eliminating some of the relays. In this figure I

have shown the simplified arrangement applied to the neutral relay system of Fig. 6. It should be understood, however, that this modification could apply equally well to the polar design of Fig. 2. Since the functions of repeating character signals and auto stopping are identical with the arrangements previously described it will only be necessary to describe the operation of the modified transfer circuit.

An inspection of Fig. 7 will show that whereas in the former systems relays RA and RB have been actuated by additional relays incorporated in the receiving transfer circuit, in the present modification the functions of the transfer circuit are incorporated in the design of relays RA and RB, no additional relays being required for the purpose of transfer. It is understood that relays RA and RB are neutral relays differentially wound, i. e. a certain current in the upper half of relay RA may be neutralized by a current of like value flowing in the lower half of the coil of relay RA. Likewise, a certain current flowing in the lower coil of relay RB may be counter-balanced by a similar current flowing in the upper coil of relay RB. In addition to the coils of relays RA and RB, the receiving transfer circuit includes contact group 4 of relay RA and contact group 3 of relay RB as well as resistances r_2 and r_3 .

Let us assume that relays RA and RB are both deenergized, having the tongues of all groups resting on the back contacts and the normal connection of group 4 of relay RA, being established. Now assume the receiving local brush to have moved in such a position as to apply battery to the receiving sixth pulse segment. Current flows through the normal or break contact of contact group 4 of relay RA, through the top half of the coil of relay RA, through the lower coil of relay RB, to ground. A parallel path is also provided through the upper contact of group 3, relay RB, through the upper coil of relay RB, through resistance r_3 to ground. Since resistance r_3 is adjusted so as to make this latter current substantially equal to the current flowing through the lower coil of relay RB, no resultant flux is established in the core of relay RB; therefore it is unable to operate. Since a differential condition is not present in the coils of relay RA, the current flowing through the upper half of its winding causes it to be operated. Before the normal connection of group 4 of relay RA is broken, the tongue of that group makes contact so as to permit current to flow from the locking resistance r_2 through the upper half of the coil of relay RA, keeping it operated, through the lower coil of relay RB, maintaining the differential condition of that relay by virtue of the fact that it counter-balances the current still flowing in the upper coil of relay RB from the sixth pulse segment via the tongue and upper contact of group 3 of relay RB.

When the receiving local brush passes off the sixth pulse segment, current no longer flows through the upper coil of relay RB, but since the lower coil is still energized by virtue of the locking current of relay RA, a flux is established in the core of relay RB, causing it to operate.

Relays RA and RB both remain locked in their operated position until the receiving local brush moves on to the sixth pulse segment on the succeeding revolution. Current now flows from the sixth pulse segment through the tongue and lower contact of group 3 of relay RB, through the lower half of the coil of relay RA. This current neutralizes the flux previously established by the

locking current flowing in the upper half of the coil of relay RA, causing it to be released. Before the tongue of group 4 breaks, however, the normal connection of that group is made, establishing a differential condition of the coils of relay RA, allowing it to remain unoperated. Current continues to flow from the sixth pulse segment, however, through both halves of the coil of relay RA through the lower coil of relay RB, keeping the latter relay in its operated position. When the local brush passes off the sixth pulse segment, battery is removed from this circuit so that relay RB is released. Since no current is now flowing in either coil of either relay, both relays remain in unoperated position until the succeeding revolution, when the above cycle of operations is repeated.

It should be noted that in order to preserve the differentiability of relay RB during the transient conditions occurring when current is being established through the upper half of the coil of relay RA and the lower coil of relay RB as well as the upper coil of relay RB at the time when battery is applied to the sixth pulse segment by the receiving local brush, the inductance of these circuits should be substantially equal. This may be accomplished by replacing resistance B with an inductance having constants substantially equal to the value of the upper half of the coil of relay RA. Due to the natural sluggishness of relay RB, however, this refinement is not generally necessary.

It may also be interesting to note that when the sixth pulse arrives on the revolution which unlocks the relays, the current flowing in the lower coil of relay RB is momentarily increased by virtue of the fact that the solid local ring resistance is now parallel with resistance A until such time as the tongue of group 4 of relay RA breaks contact. This does no harm, since at this time we are already holding the tongues of relay RB in their energized position.

While I have described the action of the receiving transfer circuit in this discussion, it is understood that the sending transfer circuit functions in an identical manner, the sixth pulse, however, being derived through intermediate relays for the purpose of auto stop control, as described in connection with former systems.

Circuits are known which, by the use of two relays, accomplish operation on alternate pulses by holding one of the two relays in its former position during the reception of the energizing pulse in a manner similar to the system described. But whereas in former systems operation depended on the simultaneous operation of independent tongues on the same relay, necessitating precise adjustments, in the present system operation is dependent on a single tongue (the tongue of group 4 of relay RA) this method having the advantage that exact adjustments are not required.

I claim:

1. Apparatus for repeating signals from a channel or channels of a multiplex telegraph circuit into a channel or channels of another circuit, comprising a pair of banks of storing relays arranged to receive intelligence signals alternately from said multiplex circuit, means for transmitting said signals in sequence from said banks at a faster rate than they are stored, and means for automatically displacing the phase relation between the reception and transmission of said signals at intervals determined by a predetermined phase displacement therebetween.

2. Apparatus for repeating telegraph character signals from a channel or channels of one circuit into a channel or channels of another circuit, comprising a pair of character storing means operating to receive said character signals alternately, means operating to transmit said stored signals sequentially at a faster rate than they are received and means controlled by a predetermined phase displacement between the reception and transmission of the signals for automatically interposing a greater phase displacement therebetween.

3. Apparatus for repeating telegraph character signals from a channel or channels of one circuit into a channel or channels of another circuit, comprising a pair of character storing means operating to receive said character signals alternately, means operating to transmit said stored signals sequentially at a faster rate than they are received and means controlled by a predetermined phase displacement between the reception and transmission of the signals for automatically transmitting spacing signals in lieu of a character at intervals, thereby interposing a greater phase displacement between the reception and transmission of the character signals.

4. Apparatus for repeating telegraph character signals from a channel or channels of one circuit into a channel or channels of another circuit, comprising a continuously operating receiving distributor, a transmitting distributor operating at a faster rate than the receiving distributor, and transfer mechanism associated with said distributors having a pair of storing means acting in alternation to receive the character signals, transmitting means operating to connect said storing means to the transmitting distributor and means controlled by the phase displacement between the reception and transmission of the character signals for transmitting spacing impulses at intervals and thereby increasing said phase displacement.

5. Apparatus for repeating telegraph character signals from a channel or channels of one circuit into a channel or channels of another circuit, comprising a continuously operating receiving distributor, a transmitting distributor operating at a faster rate than the receiving distributor, and transfer mechanism associated with said distributors having a pair of storing means acting in alternation to receive the character signals, transmitting means operating during maximum phase displacement to connect said distributors to opposite storing means and during decreased phase displacement to the same storing means and means controlled by minimum phase displacement to automatically restore said maximum displacement.

6. Apparatus for repeating telegraph character signals from a channel or channels of one circuit into a channel or channels of another circuit, comprising a continuously operating receiving distributor, a transmitting distributor operating at a faster rate than the receiving distributor, and transfer mechanism associated with said distributors having a pair of storing means acting in alternation to receive the character signals, transmitting means operating during maximum phase displacement to connect said distributors to opposite storing means and during decreased phase displacement to the same storing means and means controlled by minimum phase displacement to automatically connect spacing polarity to the transmitting distributor during

one revolution to thereby restore said maximum displacement.

7. Apparatus for repeating telegraph character signals from one circuit into a channel or channels of a multiplex circuit, comprising a pair of storing means arranged to operate in alternation, continuously operating means for setting up character signals on said storing means, a continuously operating distributor connected to said multiplex circuit, means for transferring said character signals from said storing means in sequence to said distributor, and means controlled by a predetermined minimum phase displacement between the reception of signals by said storing means and the transfer of the signals therefrom for connecting the distributor to spacing potential during one revolution to thereby increase said phase displacement to a maximum.
8. Apparatus for repeating telegraph character

signals from one circuit into a channel or channels of a multiplex circuit, comprising a pair of banks of storing relays, continuously operating means for setting up character signals alternately upon said banks of relays, a continuously operating distributor connected to said multiplex circuit, means for transferring said character signals in sequence from said banks of relays, means controlled by a predetermined minimum phase displacement between the reception of signals by one bank and the transfer of signals from the same bank to the distributor to condition said transferring means, and means coacting with said conditioning means to place spacing potential upon all relay contacts and maintain connection between the same bank and the distributor during the next succeeding revolution, thereby restoring said phase displacement to a maximum.

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