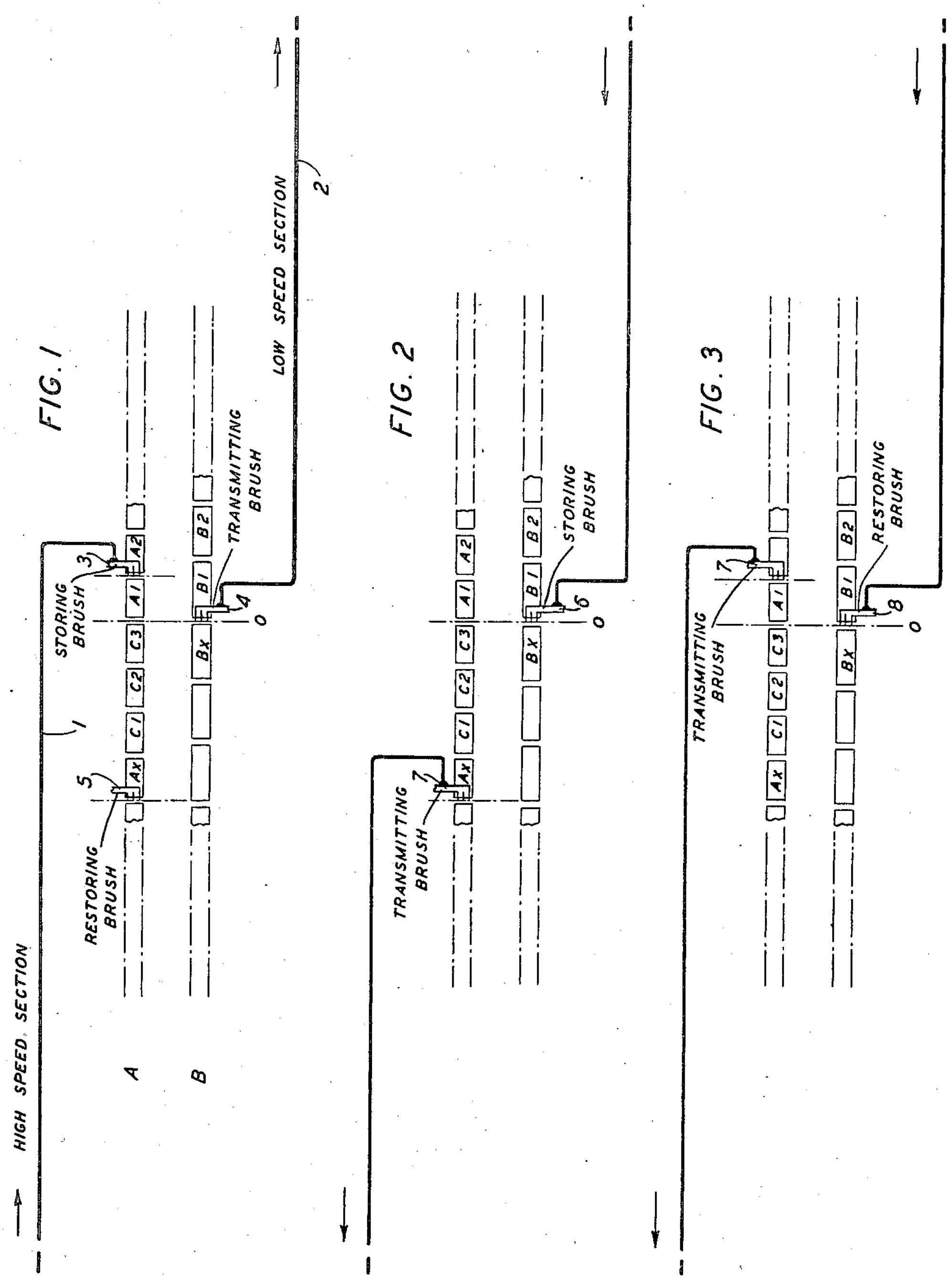
June 30, 1936. E. T. BURTON 2,046,057

MULTIPLEX TRANSMISSION SYSTEM

Filed Feb. 9, 1934 4 Sheets-Sheet 1



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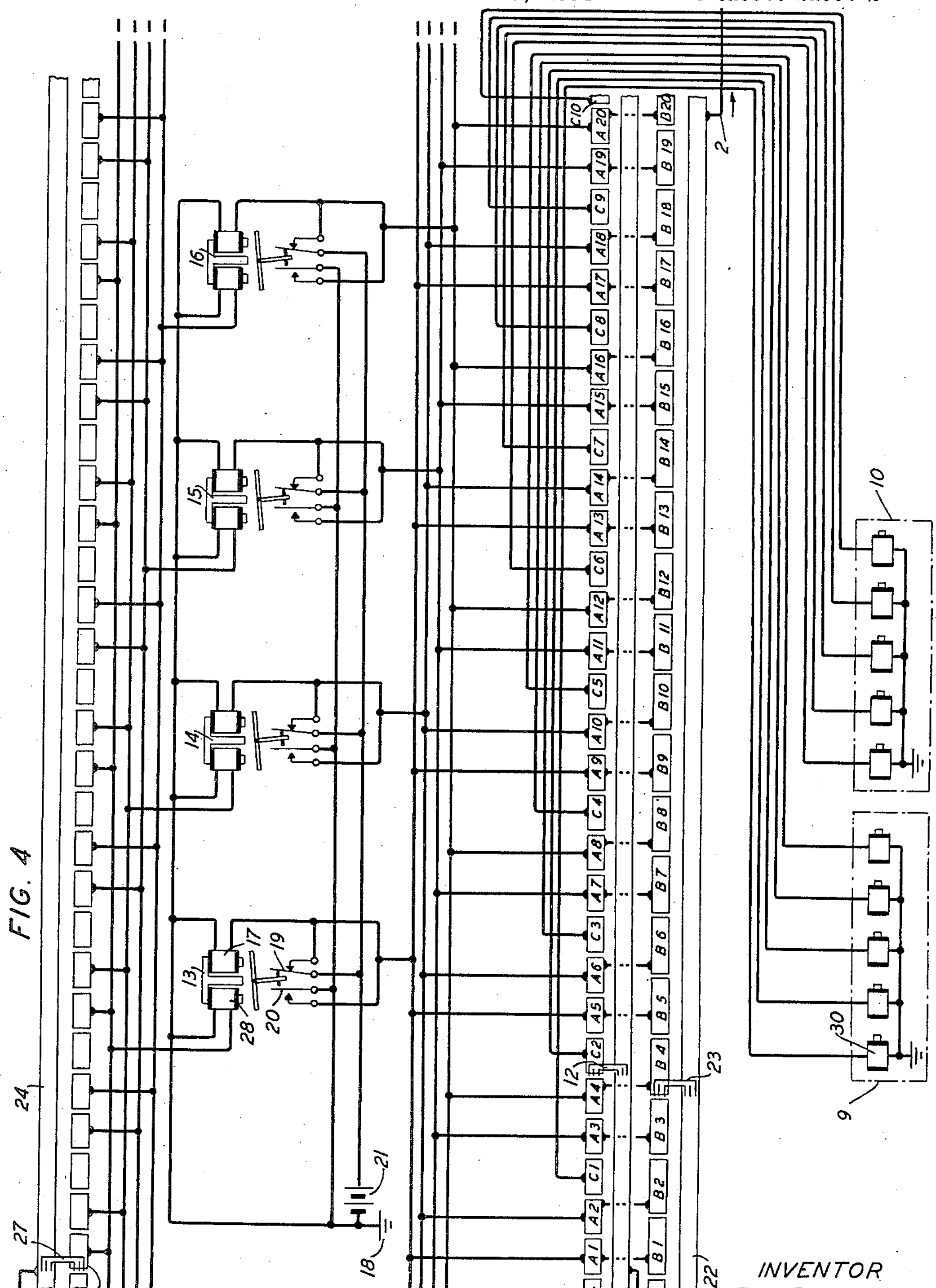

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FIG. 5

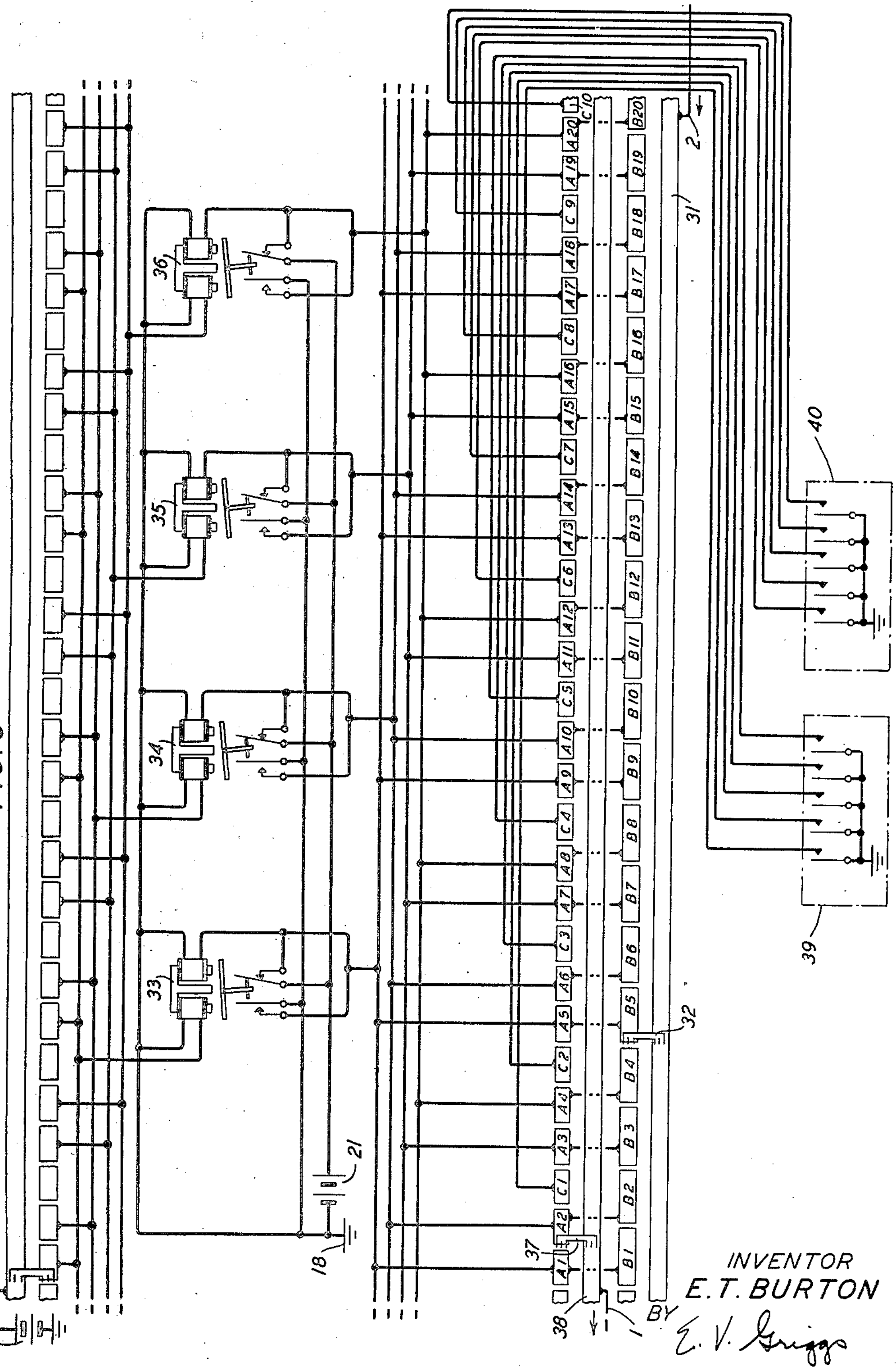

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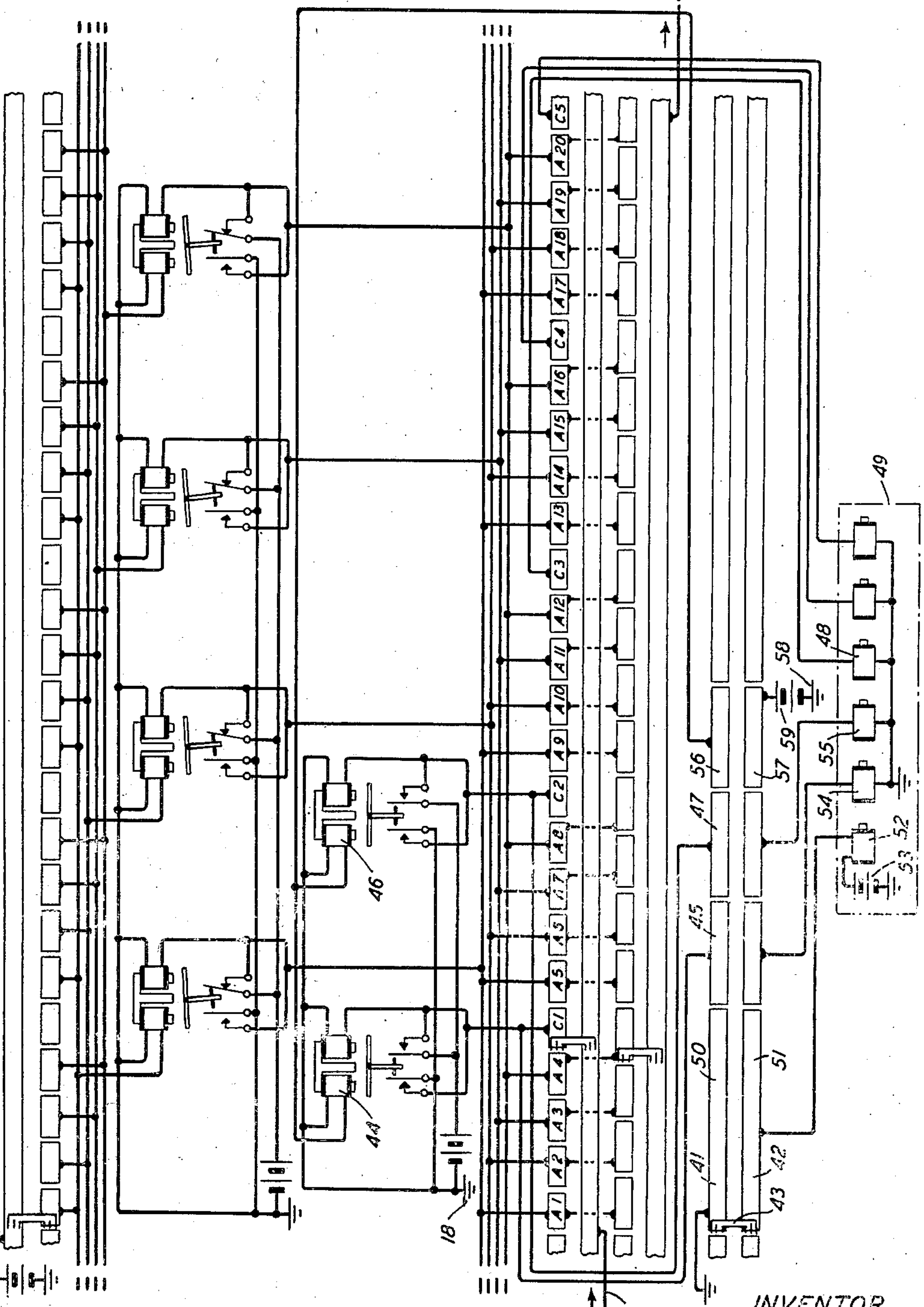
FIG. 6



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UNITED STATES PATENT OFFICE

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MULTIPLEX TRANSMISSION SYSTEM

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10 Claims. (Cl. 178—70)

This invention relates to impulse transmission systems and particularly to circuits for enabling multiplex telegraph line sections of respectively different channel capacities to operate in tandem.

It is frequently desirable to so connect a slow speed line section as, for example, a submarine cable to a high speed line section such as a telegraph land line that messages may be transferred or repeated from one to the other by automatic repeating apparatus thus enabling through transmission to be had over the sections operating in tandem. This, although enabling direct transmission without the repetition of the message by an operator at the repeating station, is wasteful of plant facilities in that it effectively restricts the message transmission capacity of the higher speed section to that of the lower speed section.

An object of the invention is to connect high speed and low speed line sections for automatic repeating operation, one to the other, without sacrificing the additional transmission capacity inherent in the higher speed section.

An additional object of the invention is to enable interconnection of two rotary distributor Baudot telegraph systems having respectively different numbers of channels to enable as many channels of the fewer channel system as desired to be associated with corresponding channels of the higher channel system without sacrifice of the excess channel capacity of the latter.

In accordance with the invention a low speed section is connected to a high speed section by repeating apparatus comprising mechanically associated rotary distributors. The distributor associated with the low speed section has fewer channels and hence fewer segments than that associated with the high speed section. The transmitting and receiving segments of the low speed section are connected by means of groups of storage elements to a similar number of receiving and transmitting segments of the high speed section. By properly choosing the number of storage elements and by correctly phasing the operations of storing, retransmitting from the storage elements and clearing the storage elements it is possible to enable one-way at a time transmission between the line sections without mutilation of signals. It is, moreover, possible to accomplish this with storage elements fewer in number than the aggregate number of impulses to be stored during one cycle of the distributor associated with the low speed section. The excess message capacity of the high speed section represented by those channels which are not repeated to the low speed section may be utilized by diverting those channels at the repeating station into local apparatus or separate circuits terminating locally or into a second low speed section.

In an alternative arrangement a single high speed section may be similarly associated at a repeating point with two low speed sections to each of which a portion of its message capacity is assigned.

The invention may best be understood by reference to the following description when read in connection with the annexed drawings in which:

Fig. 1 is a schematic diagram of a portion of a rotary distributor repeating apparatus to assist in explaining the operation of repeating impulses of a plurality of signal channels from a high speed transmission line to a low speed transmission line;

Figs. 2 and 3 are similar diagrams relating to repeating from the low speed section to the high speed section;

Fig. 4 illustrates schematically the apparatus employed at a rotary distributor repeating station for repeating four through channels from a high speed section to a low speed section together with two local drop-off channels;

Fig. 5 shows the corresponding apparatus for repeating in the reverse direction at the repeater station of Fig. 4; and,

Fig. 6 illustrates a modification of a portion of the apparatus of Fig. 4 in which a single drop-off channel is employed.

Referring to Fig. 1, a high speed section **1** having a large message capacity is associated with a low speed section **2** by rotary distributor repeating apparatus to repeat impulses from section 1 to section 2 for the through channel and to repeat impulses from section **1** to local printing circuits for the drop-off channel. Section **1** serves to impress received impulses upon a storing brush **3** which moves toward the right traversing the segments of a high speed distributor ring A. Segments A_1, A_2—A_x are allotted to impulses of the through channel to be repeated to section **2** and segments C_1, C_2, C_3 are allotted to the impulses of the drop-off channel which are repeated to the locally terminated channel apparatus. A low speed distributor ring on the same distributor is provided with segments B_1, B_2—B_x which receive impulses repeated respectively from segments A_1, A_2, etc. A transmitting brush **4** which moves to the right traverses the segments on the low speed distributor ring to transmit the repeated impulses to the low speed section **2**.

Assume that the C segments are each equal in length to the A segments and that the number n of C segments in the consecutive groups C_1, C_2, etc. is small. In order to ascertain the minimum number of storage relays which is required we may start with the fact that each segment on which the storage brush has impressed an impulse to be repeated requires a storage relay to hold the stored impulse until it can be retransmitted to section **2**. As the storage brush proceeds, one storage relay after another will come into operation and must be maintained operated until it has retransmitted its impulse to the second section after which it may be cleared or restored to normal unenergized condition. If retransmission to the line section **2** is effected at the earliest possible moment after storage and if it is followed immediately by restoring or clearing the segments of any remanent charge the number of necessary storage relays will be measured by the number of segments between the storing brush and the restoring brush.

It is evident that when transmitting brush **4** has just completed transmission from the segment B_x, or in other words, is at the position indicated by the dotted line o the restoring brush **5** associated with the segments of the high speed ring A must lag behind brush **4** by a distance corresponding to nC segments plus the A_x segment since brush **5** must not interfere with the energized condition of A_x until after brush **4** has transmitted to section **2** an impulse of B_x which corresponds to the energization of A_x. Accordingly, when brush **4** is at position o brush **5** can not be farther advanced in its travel than the initial edge of A_x.

It is also evident that before transmitting brush **4** advances beyond the dotted line o at which it is ready to begin transmitting an impulse from segment B_1 to the low speed section **2**, storing brush **3** must have passed beyond segment A_1 so that the impulse received by A_1 from the high speed section has been fully stored and so that segment B_1 has been properly conditioned by that stored impulse. In other words, when brush **4** is at line o storing brush **3** must have completely traversed segment A_1 or be one A section in advance of line o. It will accordingly be apparent that the minimum separation of the storing brush **3** and the restoring brush **5** is nC segments plus two A segments, or if the high speed C and A segments are equal in length the spacing in terms thereof is $n+2$. The number of relays must be such that there will be one relay ready to begin storing just as another has been cleared by the restoring brush or one greater than the minimum spacing between the storing and restoring brushes. Accordingly $n+3$ is the minimum number of storing relays which may be employed under these conditions.

When the direction of transmission through the repeating station is reversed so as to cause signal impulses originating at the remote terminal section **2** to be repeated to section **1**, the conditions will be as indicated in Figs. 2 and 3. Referring to Fig. 2, the storing brush **6** will just have completed its traverse of segment B_x when sending brush **7** is about to traverse segment A_x. Fig. 3 shows that when the sending brush **7** has advanced to the position where it has just completed transmission from segment A_1, restoring brush **8** is ready to begin clearing segment B_1. Therefore, transmitting brush **7** must be nC segments+one A segment behind storing brush **6** and one A segment ahead of brush **6** and one A segment ahead of brush **8**. In other words, the storing and restoring brushes of the low speed section must have a theoretical minimum separation of nC segments+two A segments.

In the special case where the C segments are constructed in equal length groups and adjacent groups are equally spaced, the minimum number of storing relays required in transmitting from the high speed section to the low speed section is equal to the spacing of the storing and restoring brushes plus 1 provided that the number of segments in a group of A segments is not less than that spacing. This relation is expressed by the equation $R_1=n+3$, where R_1 is the number of storage relays required to repeat from the high speed section to the low speed section. If the brush spacing between the storing and restoring brushes is more than sufficient to encompass the number of segments in an A group, the minimum permissible number of storage relays may be decreased by the minimum number of C segments that may be found between the storing and restoring brushes at any instant during a distributor revolution. For that special case

$$R_1=n+3-x,$$

where x is the minimum number of C segments which is at any time included between the storing and restoring brushes.

It has been demonstrated that in transmitting from the low speed section to the high speed section, the spacing between the low speed distributor storing and restoring brushes must be nC segments+two A segments, or $n+2$ in terms of equal length A and C segments. In terms of the longer B segment, the spacing is $(n+2)r$ where r is the ratio between the length of an A segment and a B segment. The number of relays R_2 which should be employed in this case is one greater, that is, $R_2=(n+2)r+1$. The foregoing formulæ hold also for the general case where the segment groups of the A ring may not be regular provided n represents the maximum number of group C segments in any group on the distributor segments.

This solution may bring up another problem. If, for example, a single channel is dropped off and the segments corresponding to the five dropped off pulses are regularly distributed, the No. 1 pulse may follow the No. 5 pulse of the previous character too closely to permit operation of the printer. This difficulty may be overcome by adding to the local printer one or more storing relays which may hold incoming pulses and deliver them to the printer as soon as it is cleared of the previously set up character.

In the case of a single drop-off channel it is also possible to separate the No. 5 and No. 1 segments from the drop-off channel by a sufficiently large interval to permit operation of the local printer without relay storing, the segments Nos. 2, 3 and 4 being located at approximately regular spacing between Nos. 1 and 5.

The most unfavorable condition with respect to the number of storing relays required for repeating channels results from grouping together all of the drop-off impulses instead of distributing them uniformly in the smallest possible group. In this case n is for ordinary Baudot transmission five times the number of drop-off channels and x very probably is zero.

Fig. 4 illustrates schematically a developed rotary distributor repeater and that part of its accessory apparatus required for repeating four channels of a high speed section **1** to a low speed section **2**. The two drop-off channels operate local printers **9** and **10**.

Section **1** is connected to deliver incoming impulses to a storing ring **11** with which are associated segments A_1, A_2, C_1, C_2, etc. Storing brush **12** which travels to the right as indicated, distributes impulses received from line section **1** to segments A_1 A_2, C_1, in turn. Associated with the A segments are four storage relays **13**, **14**, **15**, and 16 each of which is connected to one-quarter of the A segments which are equally spaced so that every A segment is associated with one of the four storage relays. Relay 13 which is typical of the four, comprises an operating winding 17 connected between segment A_1 and ground 18. Upon connection of ring 11 to segment A_1 by storing brush 12, an impulse received from line section 1 passes by way of operating winding 17 to earth causing the winding to energize and actuate its armatures 19 and 20. Armature 19 closes a holding circuit through the operating winding by way of source 21. Armature 19 also serves to connect the high potential terminal of source 21 to segment A_1 and its directly connected segment B_1 of the low speed distributor ring. Segment B_1 accordingly is maintained at a marking or significant potential until armature 19 is released. A transmitting brush 23 carried along with brush 12 by the moving element of the distributor connects ring 22 and low speed section 2 in succession to segments B_1, B_2, etc. Accordingly, as brush 23 traversed segment B_1 it caused a marking or significant impulse to be transmitted from segment B_1 to ring 22. The duration of that transmitted impulse was determined by the length of the transmitting segment B_1 so that the impulses received from high speed section 1 are effectively lengthened before retransmission to section 2.

A clearing or restoring ring 24 to which a grounded source of current 25 is connected is associated with a series of clearing or restoring segments 26 corresponding in length and number to the A segments. A restoring brush 27 successively applies restoring potential to segments 26 from source 25. Restoring winding 28 connected between ground 18 and segments 26 operates, when energized, as brush 27 engages segments 26 to overcome winding 17 and to attract armatures 19 and 20 to open the locking circuit thus restoring the relay to deenergized condition and at the same time discharging segment A_1 by way of armature 20. Since segment B_1 is directly connected electrically to segment A_1 it also is discharged to earth and "restored" or made ready to receive a new charge. Armatures 19 and 20 after deenergization of the clearing or restoring winding 28 return to a central position to which they are normally biased.

If at the instant the storing brush engages segment A_1 no marking impulse is received, storage relay winding 17 remains unenergized and no marking potential is applied to segment B_1. The drop-off channel segments C_1, etc., in general require no storing relay since impulses received by them may be transmitted directly to the local printer. Two such printers 9 and 10 have their respective electromagnets 30 each connected directly to segments C_1, C_2, etc. The corresponding segment 26 of the restoring ring is an inactive segment which merely occupies the otherwise vacant space on the distributor ring.

In order that the four storage relays 13 to 16 inclusive, may serve all of the A and B segments, the segments are movable together so that A_1 is connected directly to A_5, A_9, etc., and A_2 is likewise connected to A_6, A_{10}, etc. It is, of course, understood that if segments A_1, and B_1, for example, are charged to marking potential as a result of an impulse received from the line section 1, they will both be cleared and their associated storing relay 13 will be in normal position ready to operate anew when the storing brush 12 reaches contact A_5 with which the same relay 13 is associated. In this manner it is possible to store and repeat impulses from a relatively large number of segments without requiring an inordinate number of relays.

When transmission is to be reversed in direction, that is, to take place from low speed section 2 toward high speed section 1, it is necessary to reverse the connection with the repeater station. This may be accomplished in the general manner outlined in U. S. patent to A. M. Curtis, No. 1,632,275, issued June 14, 1927. The direction reversing mechanism forms no part of the present invention and it is accordingly not illustrated. The circuit connections for transmission in the reverse direction, that is, from section 2 to section 1, are illustrated in Fig. 5.

Referring to Fig. 5, line section 2 is shown connected for repeating four through channels to section 1 by means of apparatus comprising storing ring 31, storing brush 32, storing segments B_1, B_2, B_3, etc., storing relays 33, 34, 35 and 36, transmitting segments A_1, A_2, etc., transmitting brush 37 and transmitting ring 38. Interpolated between the A segments are the segments C_1, C_2, etc., which are associated with the printing transmitters 39 and 40 of the two drop-off channels. Inasmuch as the repeating operation is performed in the same manner as that of the circuit of Fig. 4, no additional explanation of it is necessary.

Fig. 6 discloses a portion of the rotary distributor repeater at a repeating station at which only a single drop-off channel is terminated. In that case if the C segments are distributed uniformly it may become necessary to effectively increase the time separation ensuing between the No. 5 impulse of one code character and the No. 1 impulse of the succeeding character in order to allow sufficient time for the printing operation. The figure shows only the single channel drop-off receiver and the apparatus associated therewith. The through channel apparatus is similar to that of Fig. 4.

The distinctive feature of the repeater of this figure is the local distributor ring which comprises the two similar segmented rings 41 and 42 with their brush 43 which travels together with the other brushes of the distributor in well-known manner.

The first two drop-off channel segments C_1, C_2 are each connected with an individual local storing relay to permit the first two impulses of each code character to be stored until after the printing opeartion of the previous code character has been completed. Segment C_1 is connected to storing relay 44 which, when energized, locks up to hold a marking potential on segment 45 of the local distributor ring. Similarly, segment C_2 cooperates with storage relay 46 and storing segment 47 of the local distributor ring. The remaining three segments of the local drop-off channel C_3, C_4 and C_5 are each directly connected with a selector magnet 48 of the local printer 49. The local distributor rings 41 and 42 are provided with long printing segments 50 and 51, respectively. Segment 50 is connected to ground and segment 51 is connected to printing magnet 52 in a path through source 53 to ground. Accordingly, as brush 43 sweeps into contact with segments 50 and 51 it closes the circuit of the printing magnet 52 and causes a printing operation to be performed. Segments 50 and 51 are made sufficiently long to allow plenty of time for this operation. In the meantime any impulses of the local drop-off channel which may have arrived at segments C_1 and C_2 are stored on segments 45 and 47, respectively. After the printing operation has been completed, brush 43 sweeps on over segment 45 to energize printer magnet 54 and segment 47 to energize printer magnet 55. It next engages clearing or restoring segments 56 and 57 to complete a circuit from ground at 58, source 59, segment 57, brush 43, segment 56 and the restoring winding of relay 44 to ground at 18. The armatures of relay 44 are accordingly attracted to break the locking circuit of the energizing winding and to discharge or restore segment 45. The restoring winding of relay 46 is connected in parallel with the restoring winding of relay 44 and is simultaneously operated therewith to interrupt the locking circuit of its own energizing relay and to discharge its associated local distributor ring segment 47. It will accordingly be apparent that this apparatus enables the drop-off channel segments to be uniformly distributed around the face of the distributor while at the same time permitting ample time for the printing operation after the code impulses have been received and set up to determine the character which is to be printed.

What is claimed is:

1. In combination, two multi-channel transmission lines of unequal channel capacities, terminal means connected to each line for operating its respective line at full channel capacity, and a multi-channel repeater connecting said lines for transmission in either direction over the two lines operating as a unit.

2. In combination, two transmission lines of unequal channel capacities having a terminal of one line adjacent a terminal of the other, transmitting means connected to each line for transmitting impulses thereover up to the full capacity of the respectively associated line and automatic repeating means connecting said lines for causing two way repetition therebetween of impulses corresponding to the full channel capacity of the lower capacity line.

3. In combination, two line sections, a rotary distributor, means comprising circuits connecting the adjacent terminals of said sections to divide the total line time of one section equally into a plural number of channels and to divide the total line time of the other section equally into a different plural number of channels, whereby the circuits provide through transmission over both sections for the smaller number of channels and means for diverting at the repeater the remaining channels of the higher number.

4. In combination, two transmission lines, multi-channel transmitting and receiving means connected to one of said lines for causing multiplex transmission thereover, multi-channel transmitting and receiving means connected to said second line, said second mentioned means having a different number of channels from said first mentioned means and means interconnecting adjacent terminals of said two lines for causing through transmission on a plurality of channels over the two lines operating as a single line of their combined length.

5. A transmission line, multiplex channel terminal apparatus comprising a rotary distributor connected to said line, said distributor serving to divide the time of said line into a number of channels, a separate transmission circuit, means for enabling transmission of impulses thereover, and a second transmission line having rotary distributor multiplex terminal apparatus of a number of channels equal to the combined number of channels of said first line and of said separate circuit, and means connecting a terminal of said second line with said first line and said separate circuit for causing the entire transmission thereof to be transmitted over said second circuit.

6. In combination, a transmission line, signal transmitting means connected to said line for dividing the time of said line into a number of sequentially occurring channels of equal duration, a second transmission line, signal transmitting means connected to said second line for dividing the time of said second line into a number of equal sequentially occurring channels of a duration different from that of the channels of said first-mentioned line, and automatic repeater means interconnecting said lines for causing electrical impulse repetition between channels of said lines.

7. In combination, a low speed line section, a high speed line section having a terminal adjacent the terminal of said low speed section, automatic repeater means connecting said sections for causing the full message capacity of said low speed section to be transferred to or from said high speed section, and means for diverting the remaining message capacity of said high speed section whereby both sections may be continuously worked at full capacity.

8. In combination, a low speed line section, a high speed line section, a rotary repeater connecting said sections and means connected to said repeater for causing the through transfer to and from said high speed section of the additional message capacity thereof not utilized by said low speed section, said means comprising storage devices whereby the message impulses from one section may be stored and repeated at the proper times to the other section.

9. A transmission line, means connected thereto for dividing the operation time of said line into a number of sequentially occurring channels, a second transmission line, means for dividing the operation time of the second line into a larger number of sequentially occurring channels than that of said first line, means for repeating impulses from certain channels of said first line to corresponding channels of said second line, said means comprising groups of storage elements, means in each group for repeating the impulses stored in it by one line to a second line, the number of said groups being less than the number of channels repeated thereby.

10. A repeating station, a plurality of transmission lines terminating thereat and having unequal message transmitting capacities, said station comprising rotary distributor means for dividing the line times of said transmission lines each into a number of channels individual to the respective line, means for transmitting messages over each of said lines and capable of operating each line at its full message capacity, and means connected to said lines and said rotary distributor means for transmitting through said repeater station from one of said lines messages corresponding to the full message capacity of said line.

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