ELECTRON TUBE VARIABLE IMPULSE COMMUNICATION SYSTEM

Filed Feb. 25, 1943 14 Sheets-Sheet 1

FIG. 1

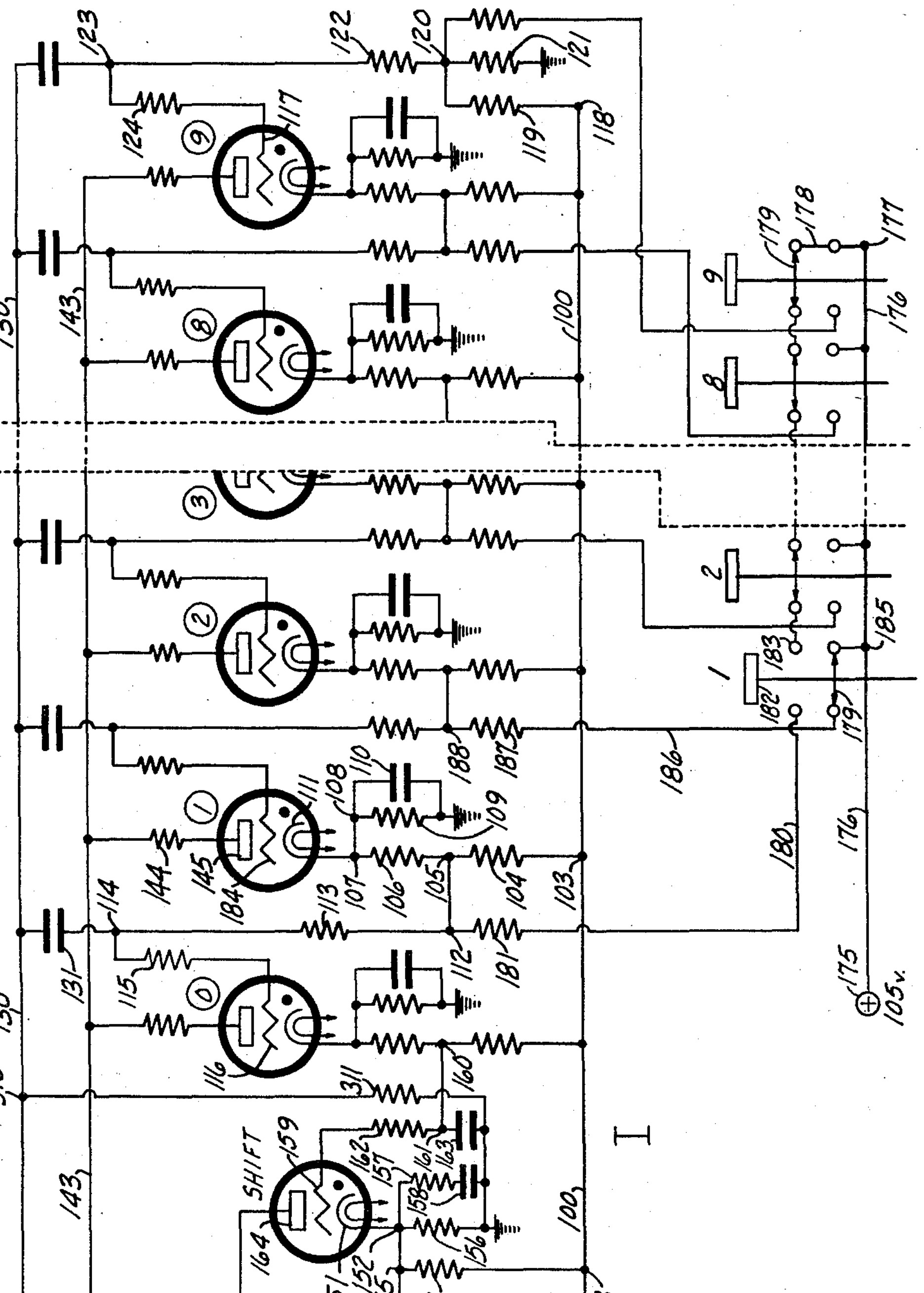

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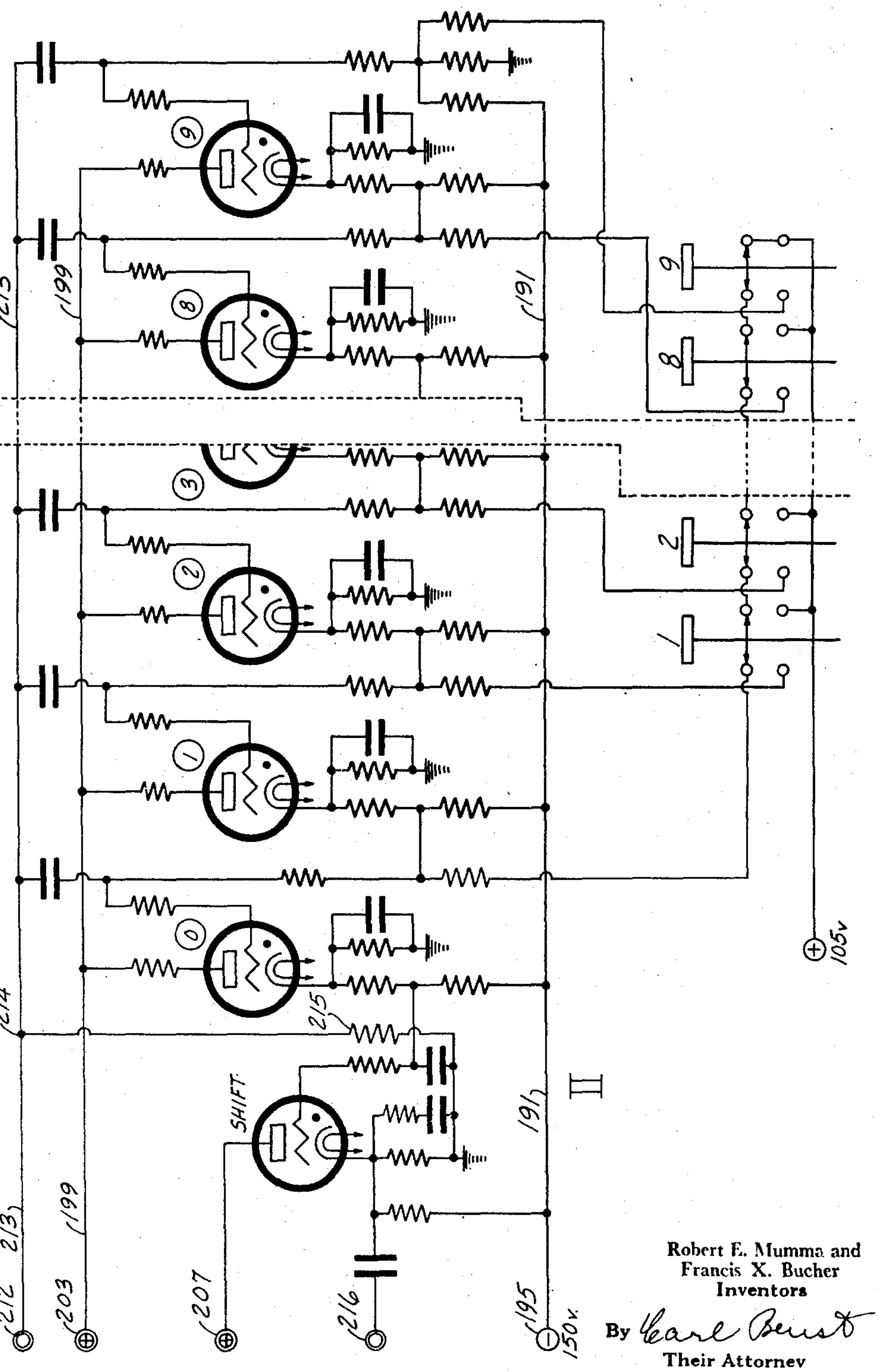
FIG. 2



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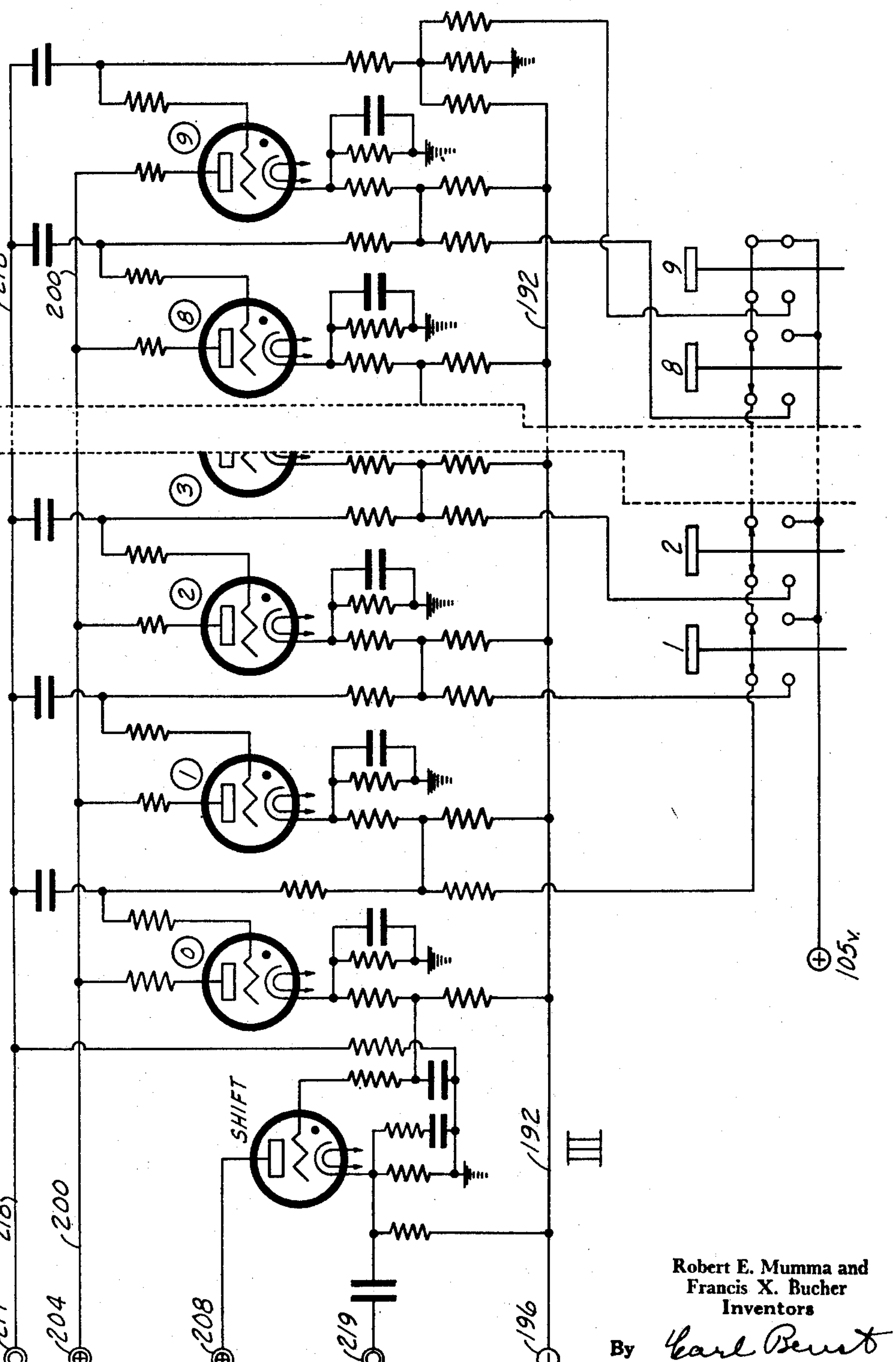
ELECTRON TUBE VARIABLE IMPULSE COMMUNICATION SYSTEM

Filed Feb. 25, 1943 14 Sheets-Sheet 3

FIG. 3



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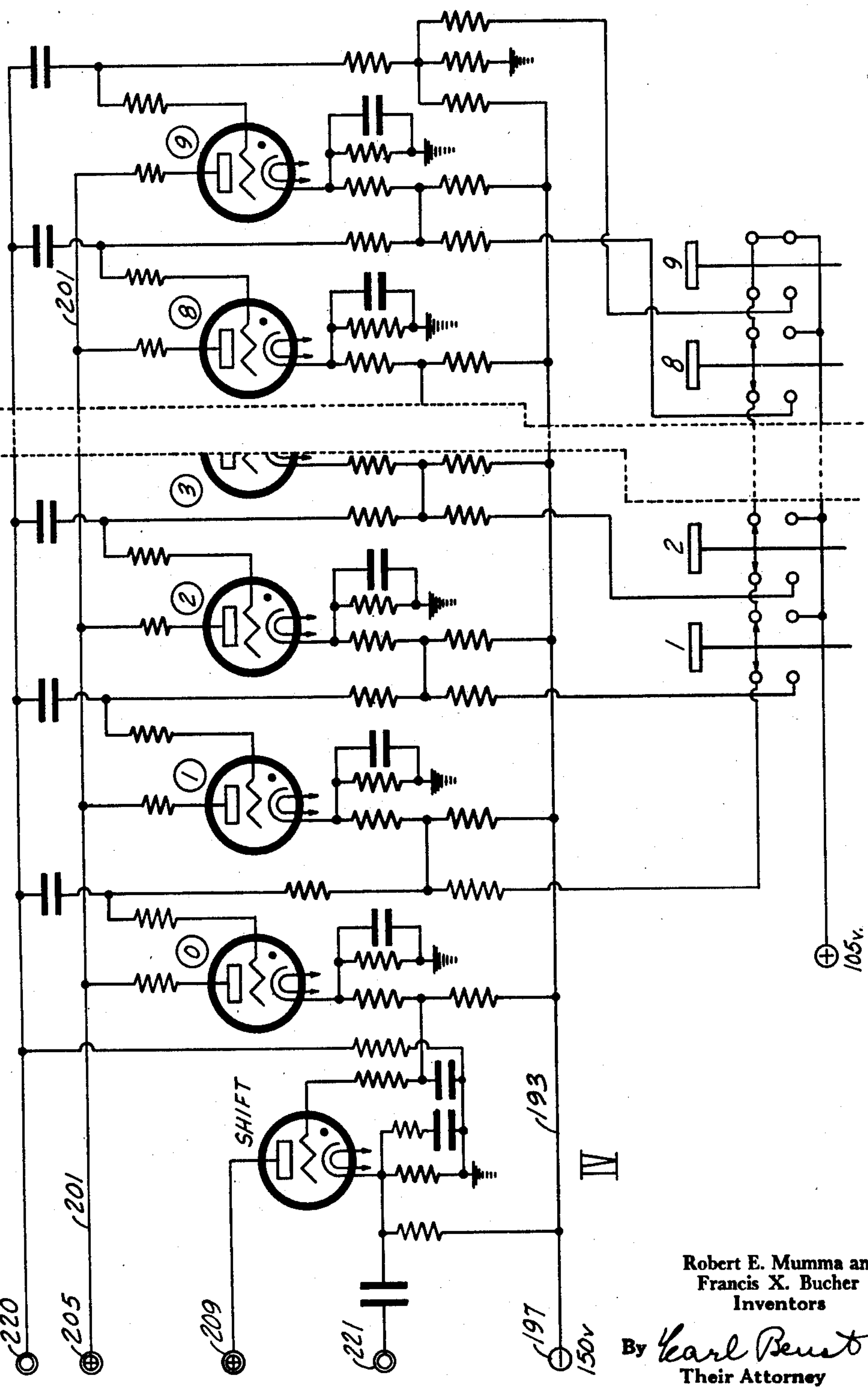
Filed Feb. 25, 1943 14 Sheets-Sheet 4

FIG. 4



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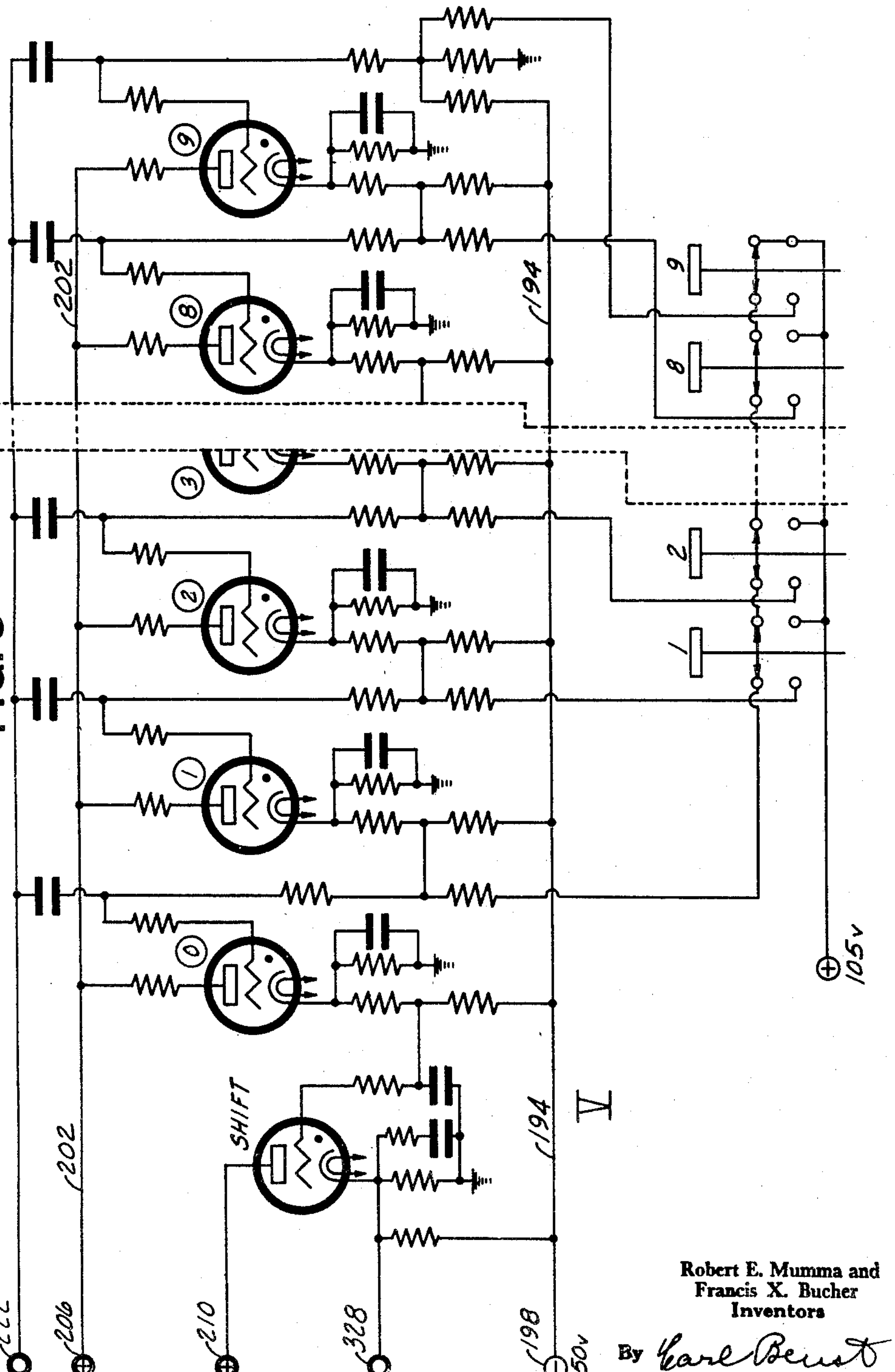
ELECTRON TUBE VARIABLE IMPULSE COMMUNICATION SYSTEM

Filed Feb. 25, 1943 14 Sheets-Sheet 5

FIG. 5



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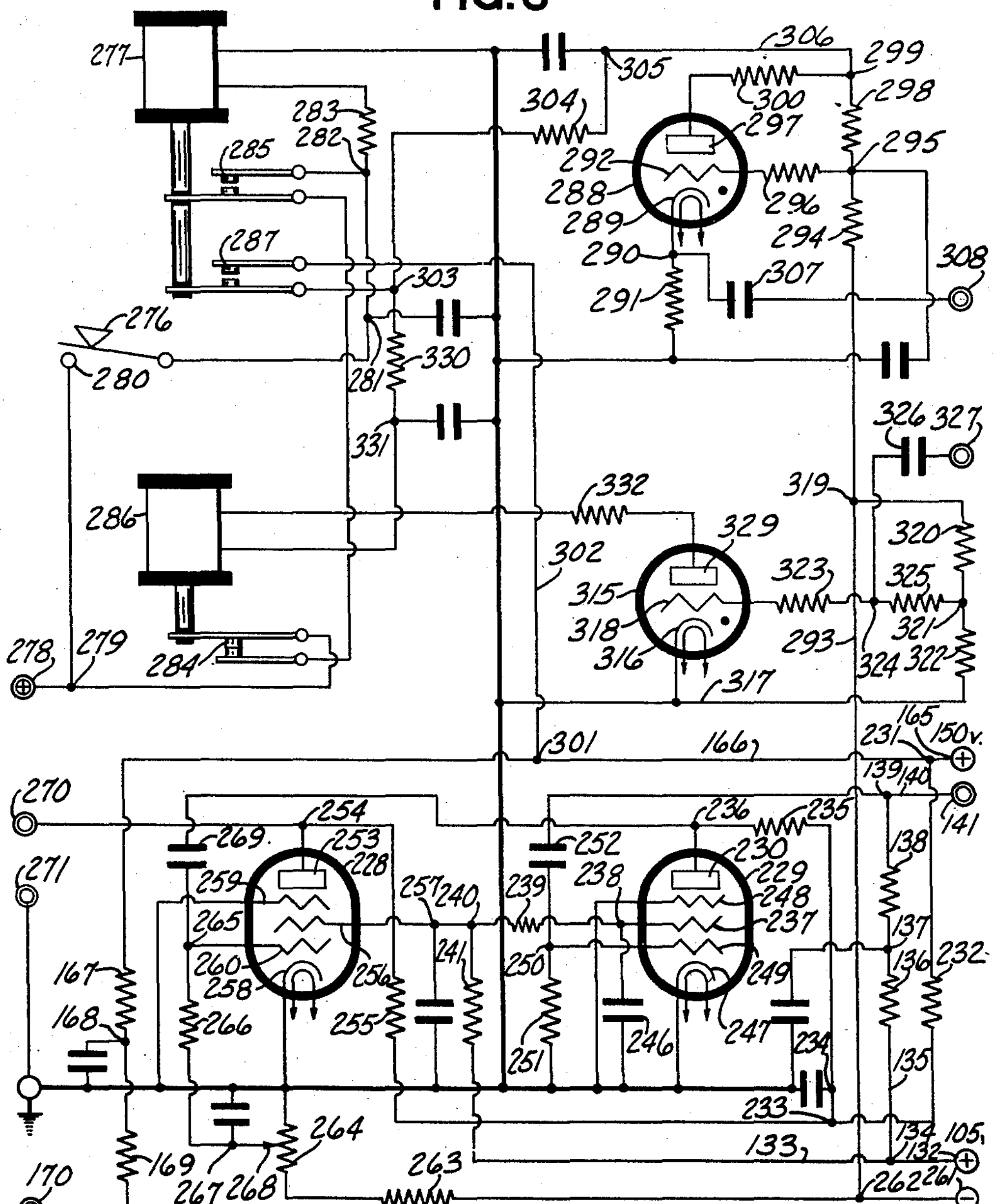
ELECTRON TUBE VARIABLE IMPULSE COMMUNICATION SYSTEM

Filed Feb. 25, 1943 14 Sheets-Sheet 6

FIG. 6



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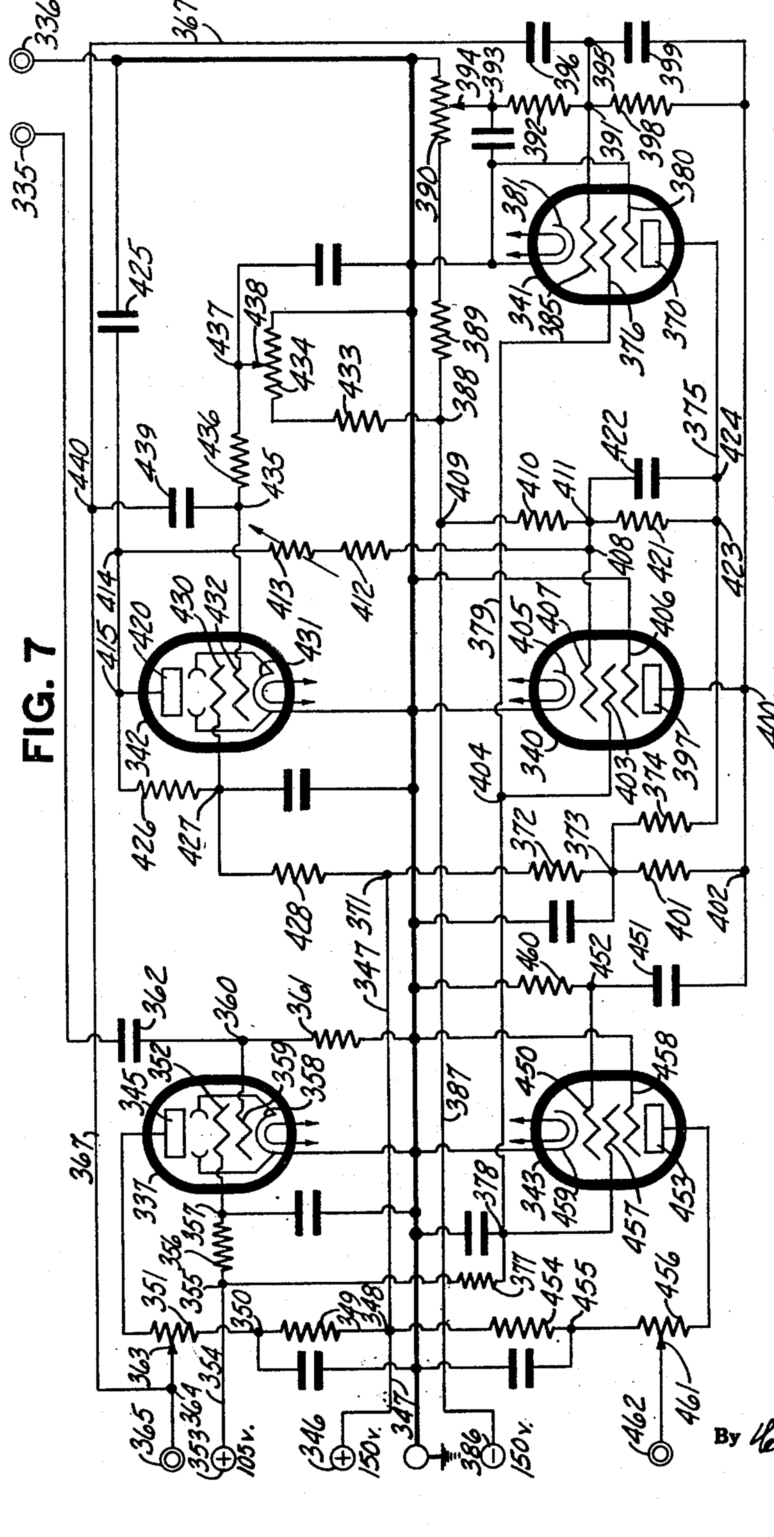
ELECTRON TUBE VARIABLE IMPULSE COMMUNICATION SYSTEM

Filed Feb. 25, 1943 14 Sheets-Sheet 7

FIG. 7



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ELECTRON TUBE VARIABLE IMPULSE COMMUNICATION SYSTEM

Filed Feb. 25, 1943 14 Sheets-Sheet 8

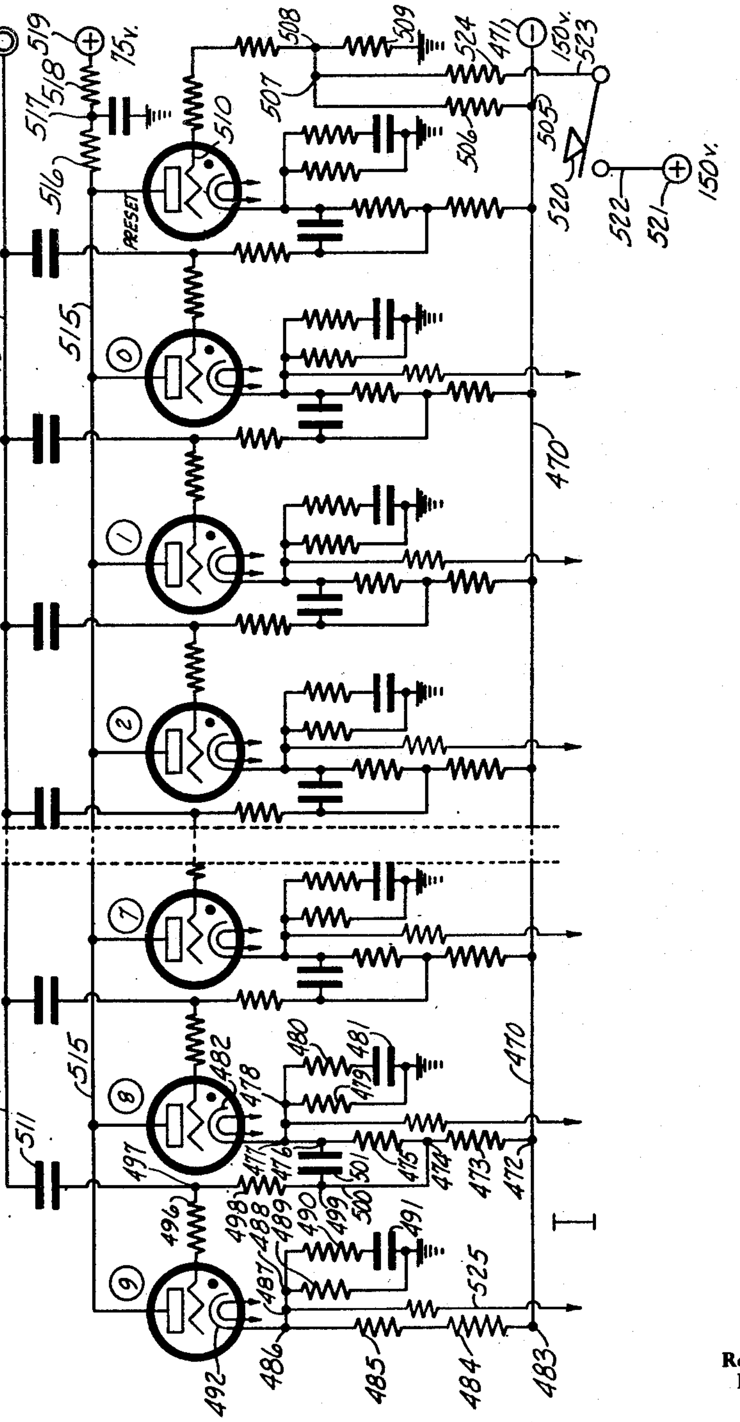

FIG. 8

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ELECTRON TUBE VARIABLE IMPULSE COMMUNICATION SYSTEM

Filed Feb. 25, 1943. 14 Sheets-Sheet 9

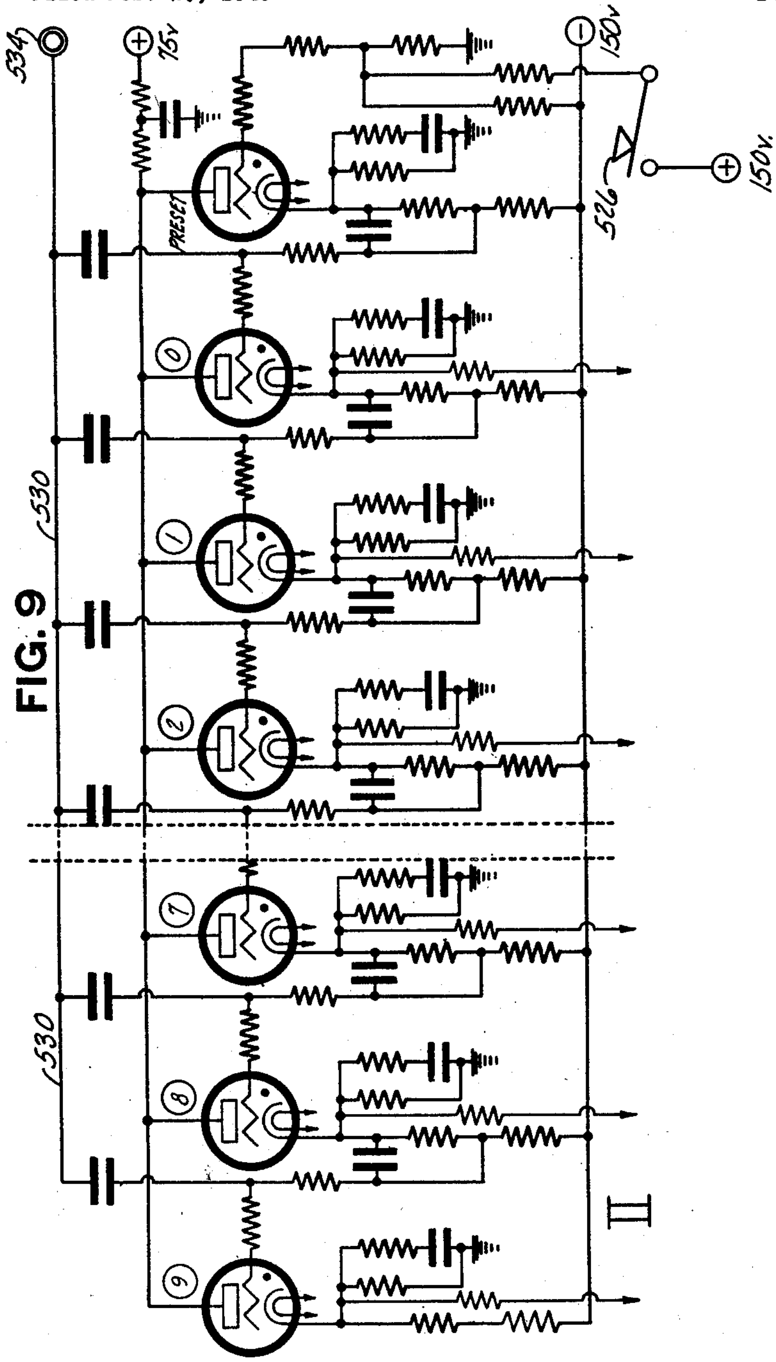

FIG. 9

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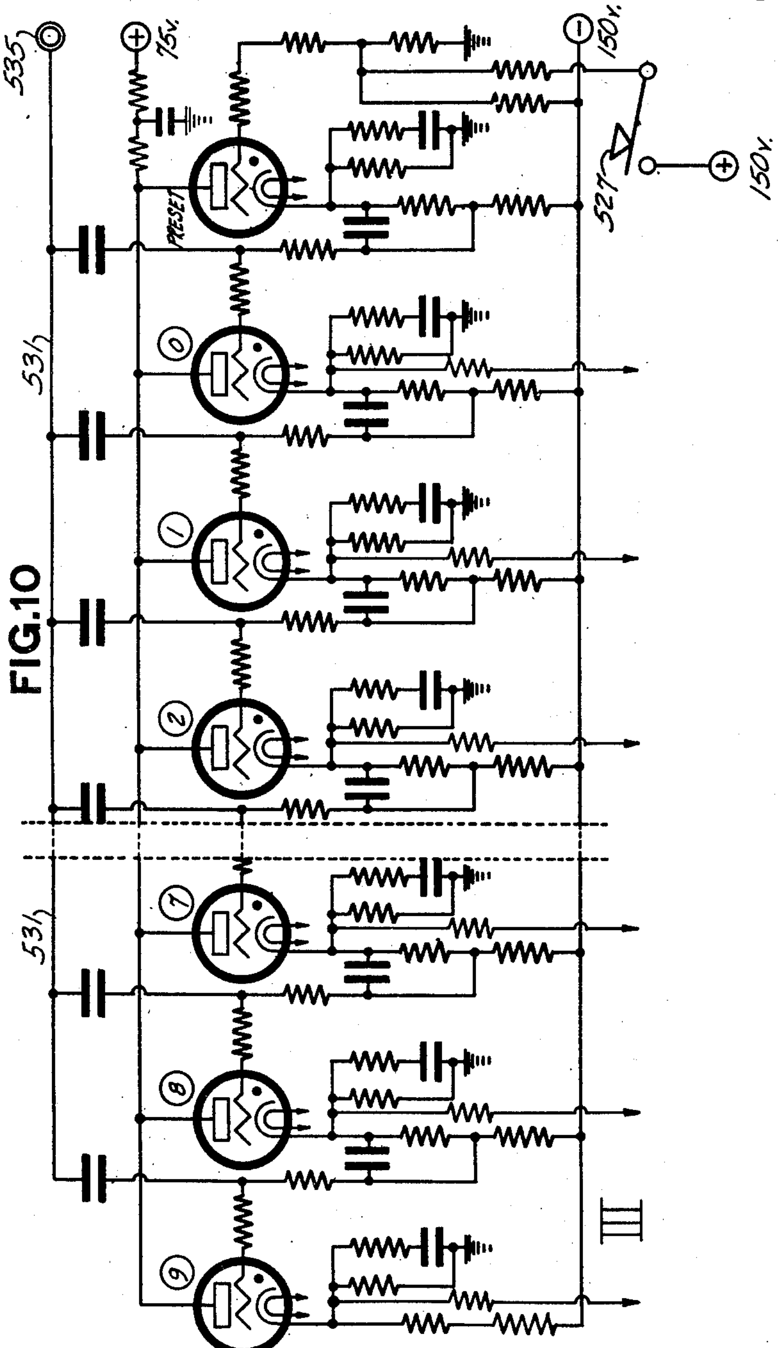
ELECTRON TUBE VARIABLE IMPULSE COMMUNICATION SYSTEM

FIG.10



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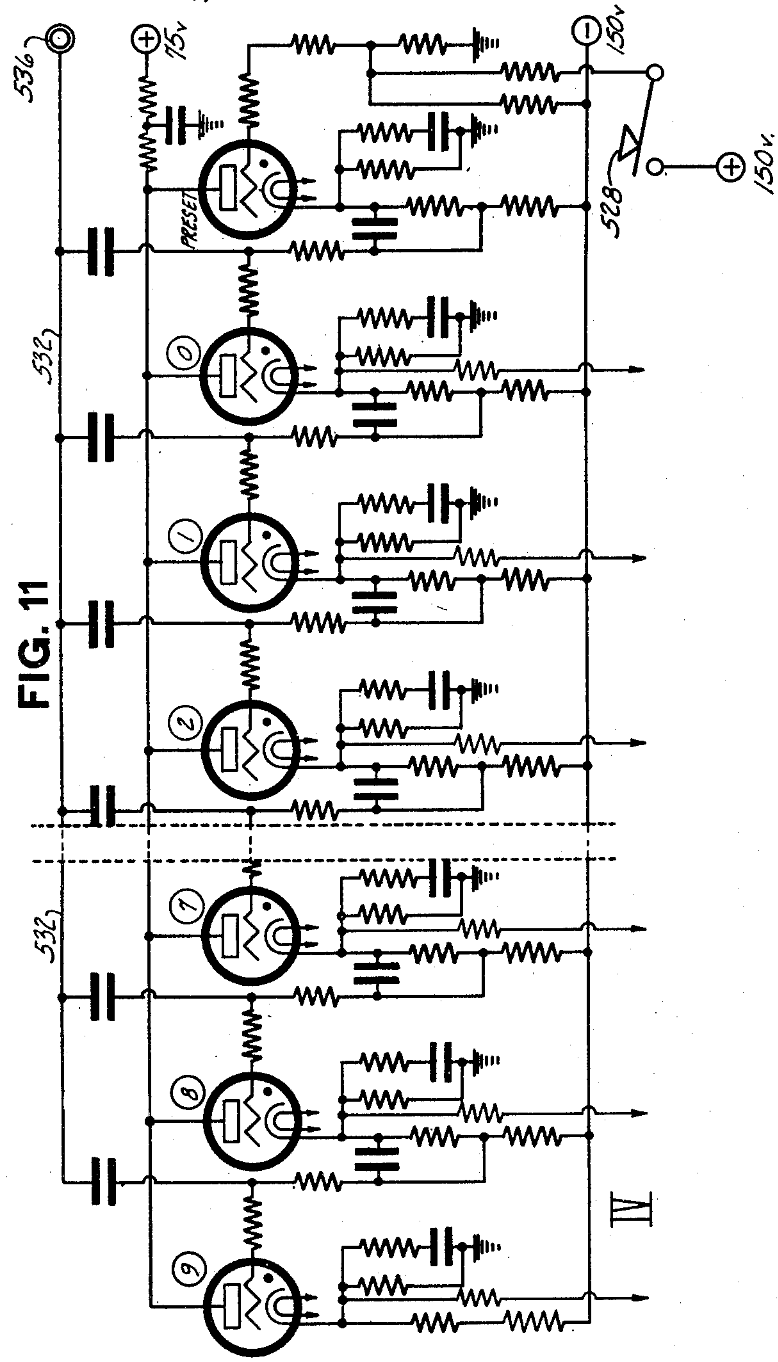
ELECTRON TUBE VARIABLE IMPULSE COMMUNICATION SYSTEM

Filed Feb. 25, 1943 14 Sheets-Sheet 11

FIG. 11



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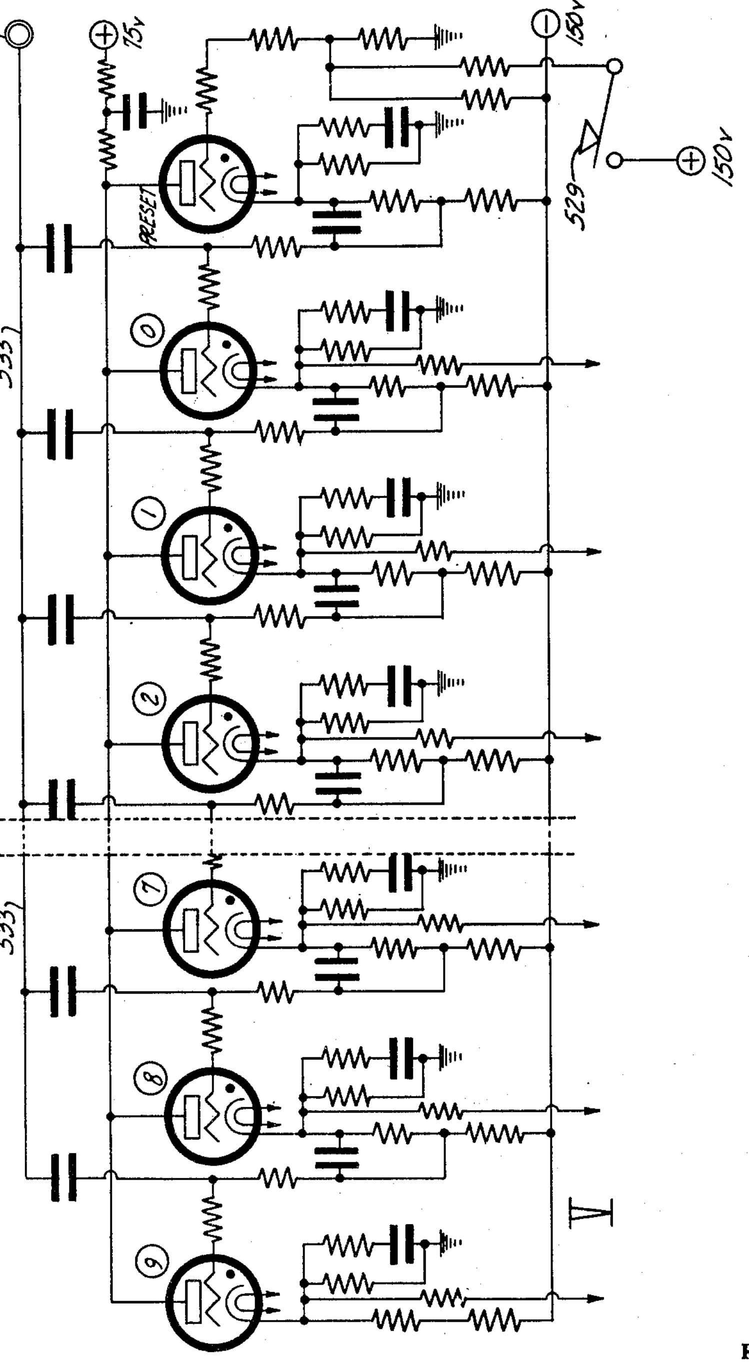
ELECTRON TUBE VARIABLE IMPULSE COMMUNICATION SYSTEM

Filed Feb. 25, 1943 14 Sheets-Sheet 12

FIG. 12



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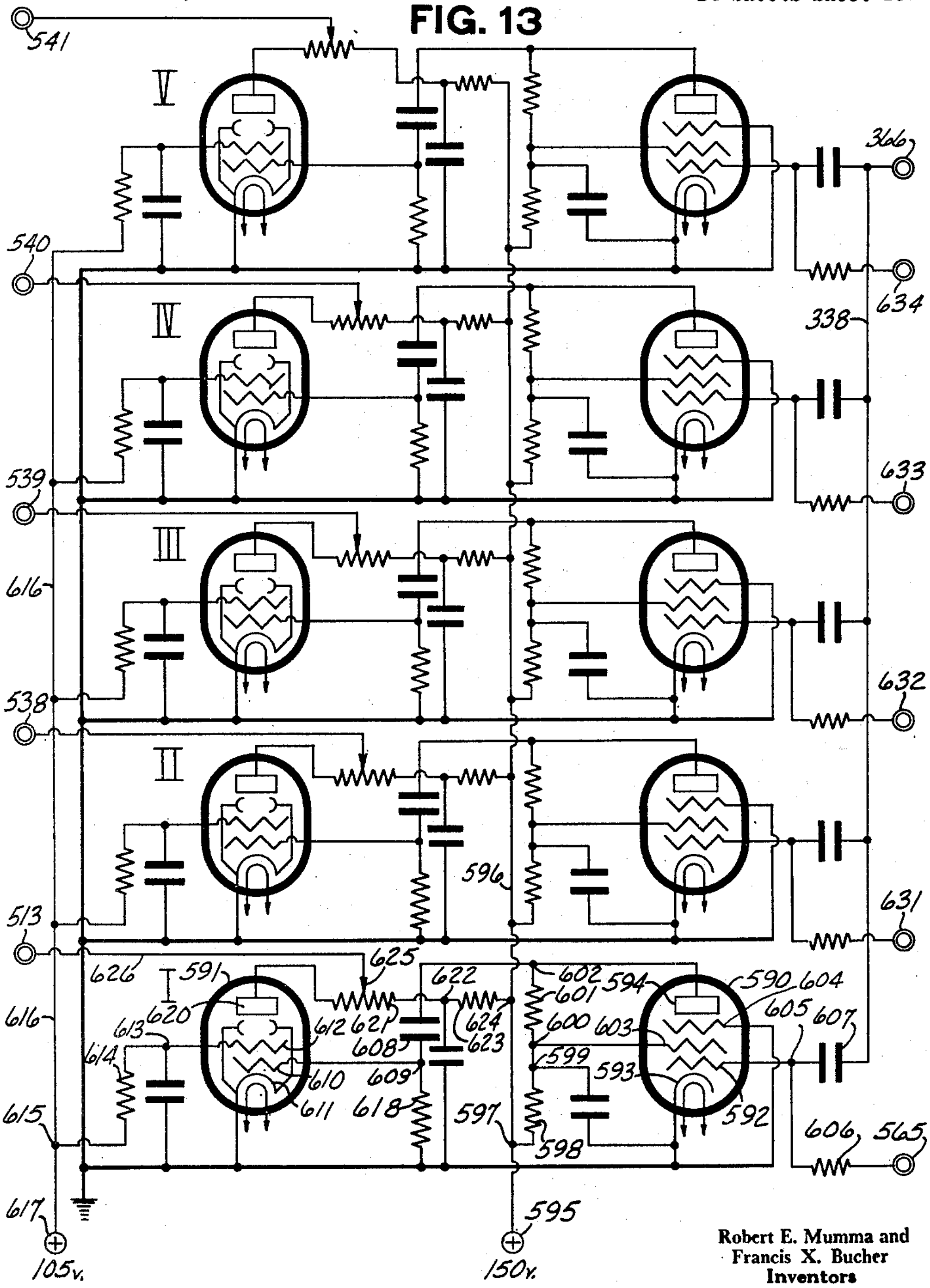
ELECTRON TUBE VARIABLE IMPULSE COMMUNICATION SYSTEM

FIG. 13



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ELECTRON TUBE VARIABLE IMPULSE COMMUNICATION SYSTEM

Filed Feb. 25, 1943 14 Sheets-Sheet 14

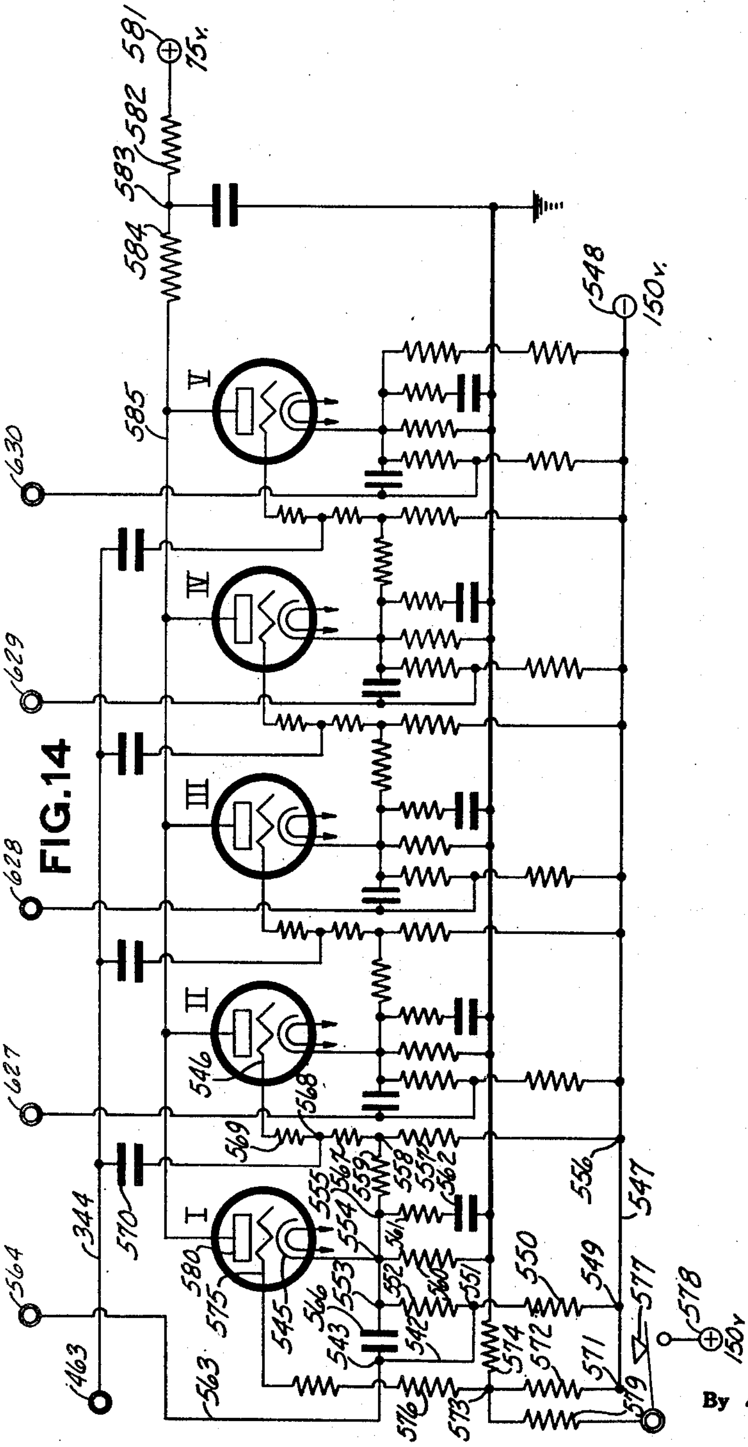

FIG.14

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Patented Oct. 19, 1948

2,451,859

UNITED STATES PATENT OFFICE

2,451,859

ELECTRON TUBE VARIABLE IMPULSE COMMUNICATION SYSTEM

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Application February 25, 1943, Serial No. 477,096

6 Claims. (Cl. 177—353)

1

This invention relates to communication systems and is directed particularly to a system in which data is transmitted in the form of bursts of different numbers of substantially identical signals.

In the instant system, each of the several symbols that may be transmitted is transformed into a burst or train containing an assigned predetermined number of substantially identical signals having like significance. Accordingly, it is the number of signals in a burst by which each symbol is represented and not the variations in the signals, per se, which make up the bursts. Under these conditions, the signals used to transmit the data can be so chosen that slight variations which might occur in the signals during transmission will not be effective to cause errors in the reception of this data. Applicants, therefore, by their novel system and means employed therein, have provided a reliable communication system in which slight variations in signals during transmission are not effective to cause erroneous reception of the data.

A sending station is provided with means for transforming the symbols into bursts of signals and generating the number of signals required in each burst according to the symbols being sent. The signals by which the symbols may be represented may take any desired form; for instance, they may consist of discrete rapidly recurring impulses and/or interruption or modulation of a continuous carrier wave. The signals can be transmitted from the sending station to a receiving station in any desirable manner, as, for instance, over a wire or by radio.

The bursts of signals representing the different symbols to be transmitted are sent one after another over a single communication channel, with a predetermined time interval or space between the bursts. The signals in the various bursts are used to cause the operation of means at the receiving station to set up direct representations of the symbols, and the spaces between successive bursts of signals are used to enable means at the receiving station to generate control signals which control routing means at the receiving station to govern the allocation and storage of the symbols in the means for setting up direct representations of the symbols.

The means for setting up direct representations of the symbols at the receiving station consists of a plurality of transforming and symbol-storing means, each being formed from a group of devices which represent the symbols. The transforming and symbol-storing means are selectively and successively rendered effective by the routing means under control of the control signals, and, when any one of these means is effective, the devices therein are differentially operated according to the number of signals in a burst to transform the signals back into a single representation of the symbol and to store this representation.

2

The apparatus at the receiving station responds to the signals when they are received, and, since it is the number of signals and not their position in a fixed cycle which is the controlling factor, there is no need to synchronize the operation of the apparatus at the sending and receiving stations either before or during a transmitting operation.

Reliable high-speed communication of data is obtained with applicants' novel arrangement because apparatus at the sending and receiving stations can generate and respond to the signals at a high frequency and because the signal bursts, which are used to represent the various symbols, are made up of signals having like significance, require only the time necessary to produce the number of signals needed to represent the symbols, and can follow one after the other in transmission without unnecessary loss of time between bursts.

Furthermore, there is no particular sequential relation between the various symbols and the number of signals which may be used to represent them, so that the number of signals which are assigned to represent any symbol may be chosen arbitrarily. Because of this condition, the symbols used most frequently can be represented by the smaller number of signals, and this will also reduce the time required for the communication of data.

It is an object of the invention, therefore, to provide a novel communication system in which variations in the signals, per se, during their transmission do not produce erroneous results in the reception of the signals.

A further object of the invention is to provide a novel high-speed means for sending and receiving data in the form of bursts of different numbers of substantially identical signals.

A further object of the invention is to provide a means for producing bursts of signals, each burst comprising a predetermined number of signals of equal amplitude and the several bursts being separated by uniform time intervals.

A further object of the invention is to provide a means upon which may be set a plurality of symbols comprising data to be transmitted, which symbols are transformed one after another into bursts of different numbers of substantially identical discrete signals representing the symbols and are sent out at spaced intervals over a single communication channel.

A further object of the invention is to provide a receiving apparatus which is not affected by variations in signals which might occur as they are transmitted thereto.

A further object of the invention is to provide means for receiving different numbers of similar discrete signals which represent symbols and transforming the different numbers of signals into representations of the symbols.

A further object of the invention is to provide a receiving apparatus for receiving bursts of impulses, which receiving apparatus contains means to generate a control signal after each burst of impulses has been received.

A further object of the invention is to provide a receiving apparatus for receiving and transforming bursts of different numbers of symbol-representing signals into single representations of the symbols, said receiving apparatus containing a plurality of transforming means for setting up said single representations of various symbols according to the number of signals in a burst, means for generating a control signal after each burst of symbol-representing signals has been received, and routing means operated by the control signals to route the different bursts of signals to different ones of the transforming means.

With these and incidental objects in view, the invention includes certain novel features of construction and combinations of parts, the essential elements of which are set forth in appended claims and a preferred form or embodiment of which is hereinafter described with reference to the drawings which accompany and form a part of this specification.

In the drawings:

Fig. 1 shows the portion of a set of keys for setting up a symbol in the sending apparatus and a portion of the symbol-transforming means controlled thereby for generating the number of impulses which will be sent to represent the symbol set up on the keys.

Figs. 2 to 5 inclusive are similar to Fig. 1 and together with Fig. 1 provide means for setting up and generating the signals to represent five symbols in succession.

Fig. 6 shows the start and stop controls for the sending apparatus and also shows the means for amplifying and sharpening the impulses which have been generated to represent the several symbols.

Fig. 7 shows the means for receiving the bursts of impulses and for creating an impulse to control a routing means after each burst is received.

Figs. 8 to 12, inclusive, show portions of the transforming and symbol-storing means in the receiving apparatus, which means consist of groups or banks of symbol-representing tubes which may be selectively set according to the symbols corresponding to the impulses sent by the sending apparatus.

Fig. 13 shows relay means for selectively directing or routing impulses to the various groups of transforming and symbol-storing means.

Fig. 14 shows a routing control device containing a plurality of sequentially operable tubes which are operated by the control signals to control the relay means which route the impulses representing various symbols into the proper groups or banks of transforming and symbol-storing means.

GENERAL DESCRIPTION

The symbols which may be sent and received by the novel apparatus may represent any selected data such as the digits of numerical notation, the letters of the alphabet, or any other arbitrary data which may be chosen.

The disclosed embodiment is shown with a capacity for automatically transmitting five symbols in succession and is arranged to transmit the digits 0 to 9 inclusive of a numerical notation.

For the purposes of this disclosure, the signals by which the symbols are represented will consist of discrete rapidly recurring negative impulses of substantially uniform amplitude, and these impulses will be transmitted from the sending apparatus to the receiving apparatus over a wire. However, it is not intended to limit the invention to this particular form of signal and transmission medium, as the invention is capable of being carried out by using other equivalent arrangements.

The sending apparatus contains five groups or banks of keys. The keys of each group represent the symbols for the digits 1 to 9 inclusive and are used for setting up symbols to be transmitted. Associated with each bank of keys is a bank of gaseous electron tubes which contains a tube corresponding to each symbol represented by the keys, and, in addition to these tubes, contains a tube corresponding to the "0" symbol, and a shift tube.

The tubes of each bank are connected in a chain to be fired automatically one after another in sequence from the "9" tube through the "0" tube, and, as they are fired, they generate the impulses which make up the burst. The depressed key in any bank selects the starting point in the firing sequence by preparing its related symbol-representing tube to be fired in response to an impulse commonly impressed on all of the symbol-representing tubes; however, if no key is depressed in the bank, the "0" tube is prepared and will be fired by the impulse. Once a tube in a bank is fired, it will start the automatic firing of the other tubes in the sequence one after another until the shift tube is fired and becomes conducting. By means of these tubes, the symbol is transformed into a series of rapidly recurring impulses. The symbol-representing tubes are connected to an impulse line and send an impulse over the line each time one of the tubes is fired, and these impulses are amplified and sharpened and sent as substantially equal-amplitude impulses to the receiving apparatus.

When the last symbol-representing tube in a chain is fired, it causes the shift tube of this bank to be fired and send an impulse to the symbol-representing tubes of the next bank of tubes to fire the prepared symbol-representing tube therein and start the sequential firing of the tubes of that bank. By means of the shift tubes, various banks of tubes are rendered operative one after another in succession and enable the impulses representing the different symbols to be sent in succession over a single communication channel. The output from these generating tubes will therefore consist of a plurality of bursts of rapidly recurring equal-amplitude impulses, one burst of impulses for each bank of tubes.

After the keys in the various banks have been set according to the symbols to be transmitted, the transmission of the symbols is initiated by the operation of a start key, which causes a firing impulse to be sent to the symbol-representing tubes of the first bank of tubes to start the sequential firing of the tubes therein. The remaining banks of tubes will be rendered operative automatically in succession, and the shift tube of the last bank will cause the termination of the transmitting operation.

The receiving apparatus contains means upon which the received impulses are impressed and which is capable of causing a control impulse to be generated after each burst of impulses; a routing means operated by the control impulses; and a plurality of transforming and symbol-storing means each consisting of a group or bank of gaseous electron tubes for transforming one of the bursts of impulses into a single representation of the symbol and storing the symbol.

Each group or bank of transforming and symbol-storing tubes contains a tube representing each symbol, and a presetting tube. The symbol-representing tubes of each bank are connected to be fired one after another in response to the impulses sent out by the sending apparatus, the order of firing beginning with the "0" tube and continuing through the tubes "1" to "9," in that order, which, it will be noted, is exactly the reverse order of the firing of the tubes in the sending apparatus. As each tube in the bank is fired, it extinguishes any previously conducting tube in the bank, and this means that only one tube will be conducting in each bank at the end of a receiving period and these conducting tubes in the various banks will correspond to the symbols received. The conducting tubes will continue to conduct after the receiving period and serve as a means for storing the symbols.

As explained earlier herein, the bursts of impulses representing the various symbols are sent out one after another in succession over a single wire, and, because of this, routing means must be provided in the receiving apparatus to distribute or allocate the bursts to the proper banks of transforming and storing tubes. The particular routing means shown herein includes a normally inoperative relay means for each bank of tubes, which relay means may be selectively rendered effective one after another to relay the bursts of impulses from a common impulse conductor in the receiving apparatus to the various banks of transforming and symbol-storing tubes.

The relay means are rendered effective one after another by means of a routing control device consisting of a series of gaseous electron tubes which are connected in a chain to be fired and rendered conducting one after another in sequence in response to the control impulses. The tubes of the routing control device are also connected so that the firing of any tube in the chain will cause any previously conducting tube of the chain to be extinguished and allow only one tube at a time to be conducting. The chain connections and extinguishing connections between the routing control tubes, therefore, enable the tubes to become conducting one at a time in sequence, and, as long as any tube is conducting, it renders its associated relay means operative to relay impulses from the common impulse conductor to its associated bank of transforming and symbol-storing tubes. While the routing means is shown as consisting of a plurality of relays, it is obvious that the routing means could consist of a commutator or a sequence switch which is capable of step-by-step operation to relay the impulses to the various banks.

The means upon which the received impulses are impressed passes these impulses to the common impulse conductor in the receiving apparatus, from which conductor the impulses are relayed selectively to the various banks of transforming and symbol-storing tubes by the several relays of the routing means. The means upon which the received impulses are impressed is also effective to control a control impulse generating means in the receiving apparatus to cause an impulse to be generated after each burst of impulses has been received.

The control impulses which are generated in the receiving apparatus are impressed on the routing control tubes to cause different ones of these tubes to be fired after the various bursts of impulses have been received in the receiving apparatus.

The operation of the receiving apparatus is as follows:

The receiving apparatus is prepared for the reception of data by causing the presetting tube of each bank of transforming and symbol-storing tubes and the first tube in the routing control device to be fired and rendered conducting.

The firing of the presetting tube in each bank of transforming and symbol-storing tubes will, through the mutual extinguishing connections, clear these banks of any previously stored symbols, and the firing of the first tube in the routing control device will likewise cause any other tube of the device to be extinguished and insure that the first entry will always be routed to the first bank of transforming and symbol-storing tubes.

The conducting presetting tube of each bank will prepare the "0" tube in its bank of tubes to be responsive to signal impulses and will continue to be conducting until symbol-representing signal impulses are relayed to that bank and cause the "0" tube therein to be fired and rendered conducting.

The conducting routing control tube renders the relay means for the first bank effective and prepares the routing control tube for the second bank for firing in response to the first control impulse to be generated.

The receiving device is now ready to receive signals. As the first burst of impulses is received, these impulses will be passed on to the common impulse conductor and relayed from the common impulse conductor to the first bank of transforming and symbol-storing tubes, and these tubes will be operated one after another in response to these impulses, the last tube to be operated being the symbol-representing tube corresponding to the symbol represented by the burst. After the first burst of impulses has been received, the control impulse generating means operates and sends an impulse to the routing control tubes. The routing control tube for the second bank has been prepared for firing by the conduction in the first tube, and, when the impulse is sent to these tubes by the control impulse generating means, the second bank routing control tube is fired and rendered conducting.

The second bank routing control tube, when it is fired, causes the first bank routing control tube to be extinguished, and thereby the first bank relay means to return to its normal inoperative state; prepares the third bank routing control tube for operation in response to the next control impulse; and renders the relay means for the second bank of transforming and symbol-storing tubes operative.

The next burst of impulses will cause the transforming and symbol-storing tubes of the second bank to be fired to set up and store the symbol represented by the second burst of impulses. As before, a control impulse is generated after this burst is received, and will cause the firing of the next routing control tube to prepare the next transforming and symbol-storing bank for the reception of the next burst of impulses. In this way, the successive bursts of impulses are routed to the various banks of transforming and symbol-storing tubes and control the setting of the various symbols therein.

After the sequence of bursts has been received, the conducting tubes representing the symbols in the various banks can be used to control an indicating means or a recording means or can be used to control the transfer of the symbols directly to other storing means for future use.

The invention is not limited to the use of a multiple-bank sending apparatus, because a single bank could be used repeatedly to send out successive bursts of impulses which the receiving apparatus would allocate and transform into successive settings representing the symbols in the same manner as explained above for the five-symbol sequence. Nor is the receiving apparatus limited to five banks of transforming and symbol-storing tubes, as it is obvious that more banks of transforming and storing tubes could be used if it were desired to increase the capacity of the receiving apparatus.

Thus it is seen that applicants have provided a novel system and means for reliably communicating data over a single communication channel at a high rate of speed.

DETAILED DESCRIPTION

Sending Apparatus

The sending apparatus is shown in Figs. 1 to 6 inclusive.

The disclosed embodiment of the invention is adapted to send five symbols automatically in succession in the form of bursts of impulses having substantially the same amplitude, which bursts contain different numbers of these impulses, depending upon the particular symbols represented thereby. The burst by which the symbol "0" is represented contains one impulse; the burst for the symbol "1" contains two impulses; and the burst for the symbol "2" contains three impulses. This relation between the number of impulses and the symbols which they represent extends to the symbol "9," which is represented by ten impulses; however, the invention is not limited to this particular relation between the symbols and the numbers of impulses assigned thereto, as any desired number of impulses can arbitrarily be assigned to represent any symbol.

In the following description, the numerals "I," "II," "III," "IV," and "V" indicate the order in which the symbols are transmitted, and similar numerals will be applied to the parts of the apparatus which take part in the transmission of these symbols.

Symbol-transforming means

Five banks of keys are provided for setting up the symbols, and associated with each bank is a symbol-transforming means which generates the different numbers of impulses by which the symbols are represented. The banks are shown in Figs. 1 to 5, inclusive, and, as the banks are substantially alike, it is believed that the operation of all the banks will be clear from a description of the elements of one bank and their operation.

In this disclosure, the values of the various applied potentials are given with reference to ground. It is not intended that the invention be limited to the use of the particular potentials and values of resistance and capacitance given in the following description, because the potentials applied to the various elements of the tubes are merely selected as convenient potentials for the disclosure, and the circuit elements of resistance and capacitance correspond in relative value to the potentials chosen. It is obvious that other potentials may be used and the values of the circuit elements adjusted accordingly to maintain the proper relation between the various parts of the circuit. Throughout the drawings, the cathode heater elements are shown conventionally.

Referring to Fig. 1, which shows a symbol-transforming means for the first symbol to be transmitted, it will be seen that the symbol-transforming means is made up of a plurality of gaseous electron tubes. These tubes are of the type having an internal potential drop of about 15 volts when conducting, and having an anode, a cathode, and a control grid which is given a negative bias with respect to the cathode and will prevent the tube from firing until this bias is reduced to less than 15 volts negative with respect to the cathode.

As many symbol-representing tubes will be included in each bank as there are symbols which may be selected for transmission, and these tubes will generate the different numbers of impulses by which the symbols are represented. In the present embodiment, each group will include a tube for the symbols for the digits "0" to "9," though in Fig. 1 only the "0," "1," "2," "3," "8," and "9" tubes are shown, the symbol-representing tubes for the digits "4" to "7" inclusive having been omitted to simplify the showing of the bank because the circuits for these tubes are identical with those of other symbol-representing tubes and the operation of the symbol-transforming means can be readily understood without a showing of them.

One shift tube "Shift" is provided for the bank and is operated to shift the control of the sending of impulses, from one bank to another, by impressing a starting impulse on another bank to start the sending of another burst of impulses after the last symbol-representing tube of one bank has operated to generate the last impulse in the burst of the symbol-representing impulses.

The circuits for supplying potential to the elements of the symbol-representing tubes and for interconnecting these tubes for sequential operation are similar for all these tubes and will be clear from the explanation of the circuits shown.

Negative potential is supplied to the cathodes of the symbol-representing tubes by means of parallel circuits, one for each tube, extending to ground from a negative potential supply conductor 100, to which a negative potential of 150 volts is applied at terminal 101. The circuit for the "1" tube is representative and extends from the supply conductor 100 at point 103 over resistor 104 of 150,000 ohms, point 105, a resistor 106 of 75,000 ohms, points 107 and 108, and over resistor 109 of 15,000 ohms and capacitor 110 of .002 microfarad in parallel, to ground.

The cathode 111 of the "1" tube is connected to this circuit at point 107 and has a negative potential of approximately 9 volts when the tube is not conducting. When the tube is conducting, the cathode is also conductively coupled to its related anode by the discharge path through the tube, so that the positive potential which is applied to the anode will also be impressed on the cathode potential supply circuit and will cause the potential of the cathode to rise from a negative potenial of 9 volts to a positive potential of about 70 volts.

Each cathode potential supply circuit is utilized to supply negative biasing potential for the control grid of the next tube in the sequence, which is, in this case, the "0" tube. From the point 105 in the cathode potential supply circuit for the "1" tube, a connection extends through point 112, over resistor 113 of 500,000 ohms, point 114, resistor 115 of 50,000 ohms, to the control grid 116 of the "0" tube and provides this grid with a negative biasing potential of approximately 56 volts. This connection between the cathode potential supply circuit of one tube and the control grid of the next adjacent tube of the series enables the potential rise of the cathode of one tube to reduce the bias of the control grid of the next tube in the sequence to a value below its critical potential and will cause the next tube to automatically fire and become conducting.

Since the "9" tube is the first tube in the sequence, the control grid 117 of this tube is given a biasing potential of the same value as the grids of the other tubes by means of a circuit which is equivalent to the other cathode potential supply circuits and extends from the negative potential supply conductor 100 at point 118, over resistor 119 of 150,000 ohms, point 120, and resistor 121 of 90,000 ohms to ground, to which circuit the grid 117 is connected from point 120 over resistor 122 of 500,000 ohms, point 123, and resistor 124 of 50,000 ohms.

Each control grid of the symbol-representing tubes is electrostatically connected to a firing impulse conductor 130, the connection for the grid 116 of the "0" tube extending from point 114 in the grid circuit, over a capacitor 131 of 10 micro-microfarads to the conductor 130. The firing impulses, which are positive potential impulses impressed on conductor 130, tend to reduce the negative bias of the control grids below their critical value, but are not sufficient to overcome the normal negative bias. The firing impulse will be effective to cause a tube to be fired only if that tube has been "primed" or has its grid bias reduced to near the critical point so that the firing impulse can reduce the bias below its critical point and cause the tube to fire and become conducting. The manner in which the tubes can be "primed" will be explained hereinafter.

Positive potential is supplied to the anodes of the symbol-representing tubes by a circuit which extends from terminal 132 (Fig. 6), upon which is impressed a positive potential of 105 volts, and continues over conductor 133, point 134, conductor 135, a resistor 136 of 250 ohms, point 137, a resistor 138 of 3,000 ohms, point 139, and conductor 140 to the common anode potential supply terminal 141 for the symbol-representing tubes.

Point 137 in this circuit is connected to ground over a capacitor of 8 microfarads, which capacitor absorbs the shock of any abrupt potential application or change in the circuit.

Terminal 141 is connected to terminal 142 (Fig. 1), to which is connected an anode potential supply conductor 143 for the symbol-representing tubes of this bank. Each of the anodes of the symbol-representing tubes of this bank is connected over a resistor of 1,000 ohms to the anode potential supply conductor 143, as, for instance,

resistor 144, over which the anode 145 of the "1" tube is connected to the anode potential supply conductor 143.

When none of the symbol-representing tubes is conducting, a positive potential of 105 volts is applied to the anodes; however, when one of these tubes is conducting, the potential will be reduced to about 85 volts due to the drop across the resistors 136, 138, and 144.

At the moment one of these tubes is fired, its cathode will remain at a negative potential of 9 volts, while the capacitor, as 110, is charging, and, due to the resistance in the common anode potential supply circuit for the symbol-representing tubes and the internal potential drop of the tube, the potential of the anode will drop to within about 15 volts of the cathode potential. This will cause a drop in potential of the anode potential supply conductor 143, which drop provides a negative potential impulse on the conductor. As the anodes of all the symbol-representing tubes of a bank are connected to the anode potential supply conductor 143, a series of negative impulses will occur on the conductor as these tubes are fired one after another. These impulses are sent to the receiving apparatus after they have been amplified and sharpened.

The drop in the potential of the anode potential supply conductor 143 is also used to extinguish any previously conducting tube which has its anode connected to the common source of anode potential for the symbol-representing tubes, which includes the resistors 136 and 138. The extinguishing action occurs because the potential of all the anodes of these tubes will drop as the potential of the anode supply conductor 143 drops, and this will cause the potential of the anode of a previously conducting tube to drop below the potential of its cathode, which has risen due to conduction in the tube, and will cause conduction to cease in that tube and enable the control grid to regain control.

Cathode 151 of the shift tube is normally supplied with a negative potential of approximately 9 volts by being connected at point 152 in a circuit extending from point 153 on the negative potential supply conductor 100, over resistor 154 of 390,000 ohms, point 155, point 152, and to ground over resistor 156 of 25,000 ohms in parallel with resistor 157 of 2,500 ohms in series with capacitor 158 of .002 microfarads. When the shift tube fires and becomes conducting, the potential of the cathode 151 will rise to a positive potential of about 110 volts, and this potential rise is used as a firing impulse to start the sequential firing of the tubes in bank II.

The control grid 159 of the shift tube obtains its negative bias from the cathode potential supply circuit for the "0" tube. The connection is from point 160 in the cathode potential supply circuit of the "0" tube and over point 161 and resistor 162 of 500,000 ohms to the control grid 159. The potential rise of the cathode of the "0" tube, when that tube is conducting, is effective to reduce the negative bias on the control grid 159 and cause the shift tube to fire and become conducting. A capacitor 163 of 3,000 micro-microfarads is connected between point 161 in this circuit and ground to delay potential rise of the control grid 159 and the consequent firing of the shift tube after the firing of the "0" tube. This delay in the firing of the shift tube provides a time interval between bursts, which interval may be made longer or shorter as desired by varying the capacity of capacitor 163.

Potential is supplied to the anode 164 of the shift tube by a circuit which starts at the terminal 165 (Fig. 6), which has a positive potential of 150 volts impressed thereon, and continues over conductor 166, resistor 167 of 250 ohms, point 168, and resistor 169 of 3,000 ohms to the common anode potential supply terminal 170 for the shift tubes. Point 168 in this circuit is connected to ground over a capacitor of 4 microfarads. Terminal 170 is connected to terminal 171 (Fig. 1), to which the anode 164 of the shift tube is connected. As in the case of the anodes of the other tubes of the bank, the potential of the anode will drop to about 15 volts above the potential of the cathode, while the capacitor 158 is charging, and this potential drop will be effective to extinguish any previously conducting tube which derives its anode potential over the resistors 167 and 169 (Fig. 6) in the common anode potential supply circuit for the shift tubes. Since the anodes of the symbol-representing tubes have a different anode potential supply circuit from that of the shift tubes, the firing of the shift tube will be ineffective to extinguish the "0" tube, which is the last symbol-representing tube in the bank to be fired. The "0" tube, therefore, which is conducting at the end of an operation of the tubes of the bank, remains in this condition until the first symbol-representing tube of the next bank is fired.

The sequential and automatic firing of the tubes of a bank always begins with a symbol-representing tube and is initiated by a firing impulse. As explained earlier herein, the control grids of the symbol-representing tubes are electrostatically connected to the firing impulse conductor 130 but are normally sufficiently negatively biased so that a firing impulse impressed on the conductor will not be effective to reduce the bias below its critical point to cause any of the tubes to be fired and rendered conducting. In order that a firing impulse will be effective to fire a tube, the tube must be "primed" by having the normal bias of its grid reduced to such a degree that the firing impulse will be sufficient to carry the bias below the critical value and cause the tube to fire and become conducting; accordingly, the selection of the tube with which the sequential operation of the tubes in the bank is to begin can be effected by the selective "priming" of the tubes. This is accomplished under control of the keys upon which the symbols may be set.

Fig. 1 shows schematically a portion of the row of keys upon which the first symbol to be transmitted may be entered. Only the keys for the digits "1," "2," "8," and "9" are shown, the keys for the digts "3" to "7" inclusive having been omitted to simplify the showing of the bank, inasmuch as the circuits controlled by the omitted keys are similar to the circuits shown and the operation of the keys to selectively prime the tubes can be understood from the circuits shown.

The keys of the bank are normally in an undepressed condition, and when in this position they complete a priming circuit to the "0" tube, which circuit starts at terminal 175, upon which a positive potential of 105 volts is impressed, and continues over potential supply conductor 176, point 177, conductor 178, key-controlled contacts, as 179, in series, and over conductor 180 and resistor 181 of 300,000 ohms to point 112 in the circuit to the control grid 116 of the "0" tube.

When any key of this bank is depressed, it interrupts the priming circuit described above and closes a priming circuit from the potential supply conductor 176 to the control grid of its related symbol-representing tube. The "1" key 182 (Fig. 1) is shown depressed, interrupting the priming circuit to the "0" tube at the point 183 and completing a priming circuit to the control grid 184 of the "1" tube. The priming circuit for control grid 184 extends from point 185 on the potential supply conductor, over contact 179 of the depressed "1" key, conductor 186, and over resistor 187 of 300,000 ohms to point 188 in the circuit to control grid 184.

The application of positive potential by this circuit to the control grid 184 of the "1" tube reduces the negative biasing potential of the control grid 184 almost to its critical point, and, when the firing impulse is impressed on the tubes, the bias of the control grid of the "1" tube will be reruced to within 15 volts negative with respect to the potential of the cathode, and the tube will fire and become conducting. In a similar manner, the closure of a priming circuit to any of the other symbol-representing tubes will select that tube to begin the sequential and automatic firing of the tubes of the bank.

The operation of the symbol-transforming means shown in Fig. 1, by which the burst of impulses corresponding to the first symbol to be transmitted is obtained, will now be explained.

The key 182 corresponding to the digit "1" has been depressed to interrupt the priming circuit to the "0" tube and complete the priming circuit for the "1" tube. A firing impulse is impressed on the firing impulse conductor 130 and causes the firing of the "1" tube. At the moment the "1" tube is fired, its anode potential will drop because of the resistor 144 and the resistors 136 and 138 in the symbol-representing tube anode potential supply circuit, causing a drop to occur on the conductor 143, terminal 142, and terminal 141 (Fig. 6) of the anode potential supply circuit, which drop is amplified and sharpened to provide an impulse to be sent to the receiving apparatus. The potential of the cathode of the conducting "1" tube will rise and, through the connection between point 105 in its potential supply circuit and the control grid 115 of the "0" tube, will cause the potential of the control grid 116 to rise and reduce the bias below its critical value and cause the "0" tube to fire and become conducting. The potential of the anode of the "0" tube will drop and cause another impulse on conductor 143, terminal 142, and terminal 141 in the anode potential supply circuit, which impulse will also be amplified and sharpened to provide another impulse to be sent to the receiving apparatus, and, in addition, the impulse on conductor 143 will also extinguish the conducting "1" tube. The potential of the cathode of the "0" tube will rise and cause the potential of the grid 159 of the shift tube "Shift" to rise, reducing its bias below its critical value and causing the shift tube to fire and become conducting.

There is a predetermined delay in the potential change on the control grid 159, due to the capacitor 163, which connects the point 161 in this circuit to ground, which delay provides the time interval or spacing between the successive bursts of impulses.

When the shift tube fires, there will be a potential drop in its common anode supply circuit, due to the resistors 167 and 169. However, this drop will not be effective to extinguish the "0" tube, because its anode is included in a different anode potential supply circuit. The potential rise of the cathode 151 of the shift tube is impressed on terminal 189 and is used as a starting impulse for the next bank of tubes to be fired.

It is seen that, during the sequential firing of the tubes of the bank, two impulses will occur on the terminal 141 for controlling the amplifying and sharpening tube, which amplify and sharpen the impulses before they are sent to the receiving apparatus. After the signal-generating impulses have been provided, an impulse will be impressed on the terminal 189 to cause the firing of the primed tube in the next bank of tubes. Also, it will be noted that, at the end of the operation of the tubes of a bank, the shift tube and the "0" tube will remain conducting. These tubes will be extinguished in a manner to be described later.

Each of the other symbol-transforming banks operates in the same manner as the bank described above. The banks shown in Figs. 2, 3, 4, and 5 generate the impulses which represent the second, third, fourth, and fifth symbols, respectively, and are accordingly numbered "II," "III," "IV," and "V" to indicate the sequence of their operation.

The coordination and interconnections between the various symbol-transforming banks which generate the impulses for the five symbols are as follows:

Each of the negative potential supply conductors 191, 192, 193, and 194 for the banks "II," "III," "IV," and "V" is connected, respectively, to a terminal as 195, 196, 197, and 198, upon which is impressed a negative potential of 150 volts.

The symbol-representing tube anode potential supply conductors 199, 200, 201, and 202 for banks "II," "III," "IV," and "V" have their terminals 203, 204, 205, and 206 connected to the common supply terminal 141 (Fig. 6), so that these supply conductors for all the banks will be connected together at the terminal 141 and from this terminal will be connected over the common resistors 136 and 138 to the source of potential. In this network, the firing of any symbol-representing tube in any bank will cause a potential drop in the supply conductors of all the banks, thus enabling the firing of a tube in any bank to extinguish a previously conducting tube in any other bank; for instance, the "0" tube, which remains conducting when the operation in the first bank is completed, is extinguished by the firing of the first symbol-representing tube in the second bank. This arrangement also enables the firing of a tube in any bank to cause a potential drop at the terminal 141, which drop can be amplified and sharpened and sent as an impulse to the receiving apparatus.

The anodes of the shift tubes of the various banks are all connected to the common anode potential supply circuit by having the terminals 207, 208, 209, and 210 (Figs. 2, 3, 4, and 5), to which they are connected, connected with the terminal 170 (Fig. 6). The potential drop of the anode of any shift tube, as the tube is fired, will cause any previously conducting shift tube to be extinguished, thus enabling the firing of the shift tube for the second bank to extinguish the shift tube of the first bank.

The various banks of tubes are connected for sequential operation by having the firing impulse conductor of a bank connected to the cathode of the shift tube of the bank previously operated. The terminal 189 (Fig. 1) is coupled by capacitor 211 of .001 microfarad to the cathode 151 of the shift tube of the first bank and is also connected to the terminal 212 (Fig. 2), to which the firing impulse conductor 213 of the second bank is connected, so that the potential rise of the cathode 151, as the shift tube is fired, can be impressed on the firing impulse conductor 213 of the second bank to fire any primed symbol-representing tube therein and initiate the sequential firing of the tubes of the second bank. Point 214 on the firing impulse conductor 213 is connected to ground over resistor 215 of 15,000 ohms. The capacitor 211 and the resistor 215 serve to sharpen the firing impulse impressed on firing conductor 213 when the shift tube of the first bank is fired, so that the firing impulse will be effective in the firing of only the primed tube of the sequence. The terminal 216 (Fig. 2), which is electrostatically coupled to the cathode of the shift tube of the second bank, is also connected to the terminal 217 (Fig. 3), to which the firing conductor 218 of the third bank is connected. The terminal 219 (Fig. 3) is connected to the terminal 220 (Fig. 4) to start the sequential operation in the fourth bank, terminal 221 (Fig. 4) is connected to terminal 222 (Fig. 5) to start the sequential operation in the fifth bank after the fourth bank has completed its operation. By means of these connections, the impulses for the five bursts can be formed automatically in succession.

Each of the symbol-transforming banks of tubes has a bank of keys, similar to the bank shown in Fig. 1, for selectively closing priming circuits to the symbol-representing tubes therein.

Impulse amplifying and sharpening means

As explained earlier herein, the signals which are transmitted in the novel communication system are such that variations which might occur in the signal during transmission are not effective to produce erroneous results at the receiving apparatus. In the instant embodiment, the signals which are generated by the symbol-transforming means are sharpened and amplified until they have a much greater amplitude than is necessary for the proper operation of the receiving apparatus, and this allows reasonable variations in the amplitude of the signal to occur during transmission without causing an improper operation of the receiving apparatus.

The means for amplifying and sharpening the impulses before they are sent to the receiving apparatus is shown in Fig. 6 and consists of a pair of vacuum tubes 228 and 229.

Tube 229 has a zero bias and is normally conducting. The anode 230 has positive potential applied thereto from terminal 165, the connection being over point 231, resistor 232 of 250 ohms, points 233 and 234, resistor 235 of 5,000 ohms, and point 236. Point 234 is connected to ground over a stabilizing capacitor of 8 microfarads. Screen grid 237 is connected to terminal 132, to which a positive potential of 105 volts is applied, the connection being over point 238, resistor 239 of 750 ohms, point 240, and resistor 241 of 250 ohms to conductor 133. A stabilizing capacitor 246 of 4 microfarads is connected between point 238 and ground. The cathode 247 and the suppressor grid 248 are connected directly to ground, and the control grid 249 is connected to ground over point 250 and resistor 251 of 10,000 ohms.

Point 250 in the circuit of control grid 237 is coupled over capacitor 252 of 10 micro-microfarads to terminal 141, the potential of which terminal drops to provide a negative impulse each time a symbol-representing tube in any bank is fired. These negative impulses are impressed on the control grid 237 and reduce conduction in tube 229. Since tube 229 is normally conducting, its anode 230 will normally have a positive potential of about 20 volts due to the drop across resistor 235, but, as conduction is reduced in the tube 229, by the negative impulses impressed on the control grid 237, the potential of the anode 230 will rise toward 150 volts and will provide positive impulses which are used to control tube 228.

Tube 228 is normally non-conducting but is rendered conducting each time a positive potential impulse occurs on the anode 230 of tube 229. Of the elements of tube 228, the anode 253 is connected over point 254 and resistor 255 of 5,000 ohms to point 233 in the circuit previously traced for the anode 230 of tube 229; the screen grid 256 is connected over point 257 to point 240 in the circuit previously traced for the screen grid 237 of tube 229; and the cathode 258 and the suppressor grid 259 are directly connected to ground. Point 257 in the screen grid circuit is coupled to ground over a stabilizing capacitor of 4 microfarads.

Control grid 260 of tube 228 is given a negative bias by being conected to a circuit which starts at terminal 261, upon which a negative potential of 150 volts is impressed, and continues to ground over point 262, resistor 263 of 100,000 ohms, and resistor 264 of 25,000 ohms. The control grid is connected to this circuit over point 265, resistor 266 of 50,000 ohms, point 267, and an adjustable potential-tapping member 268, which cooperates with the resistor 264 to provide the desired negative bias for the control grid. Point 267 is coupled to ground over a stabilizing capacitor of 10 microfarads.

Point 265 in the control grid circuit is electrostatically coupled to point 236 in the anode circuit for tube 229 over a capacitor 269 of 20 micromicrofarads, which coupling enables the positive potential impulses, which occur on point 236 when conduction is reduced in tube 229, to reduce the negative bias on the control grid of tube 228 and render that tube conducting.

Since tube 228 is normally non-conducting, its anode will normally have a positive potential of 150 volts, but this potential is reduced by the drop across resistor 255 each time the tube becomes conducting in response to an impulse impressed on control grid 260, and these potential drops which occur at anode 253 are impressed as output impulses on output terminal 270, point 254 in the anode circuit being connected to terminal 270, which, with terminal 271, forms the output terminals for the sending apparatus.

In the above manner, the negative impulses which are generated by the firing of the symbol-representing tubes are amplified and sharpened for transmission to the receiving apparatus.

Symbol transmission initiating and terminating means

After the symbol-representing keys of the various banks have been set to prime their corresponding symbol-representing tubes, the transmission of these symbols is initiated by a momentary depression of the start key 276 (Fig. 6), which closes the energizing circuit for the starting relay 277; the circuit extends from the terminal 278, upon which may be impressed any desirable positive potential, to the point 279, thence over the contacts 280 closed by the key 276, points 281 and 282, resistor 283 of 2,500 ohms, and over the winding of the starting relay 277 to ground. Point 281 in this circuit is connected to ground over a stabilizing capacitor, of .1 microfarad. When the starting relay 277 is energized upon the closure of contact 280 by the start key 276, it closes a holding circuit for itself from terminal 278, point 279, normally closed contacts 284, contacts 285 closed by the starting relay, point 282, and over resistor 283 and the winding of the starting relay 277 to ground. This circuit will maintain the starting relay in energized condition after the starting key has been released and until the normally closed contacts 284 are opened by the energization of the stop relay 286, in a manner to be explained hereinafter, to terminate a transmitting operation.

The starting relay 277 also closes contacts 287 to cause the firing of a start tube 288, which sends an impulse to the firing impulse conductor 130 (Fig. 1) of the first symbol-transforming bank.

Start tube 288 (Fig. 6) is a gaseous electron tube of the type described earlier herein. This tube has its cathode 289 connected to ground over point 290 and resistor 291 of 25,000 ohms. Before the starting relay is energized, the control grid 292 of the start tube is given a negative potential bias of 150 volts by means of a circuit which starts at the terminal 261, upon which is impressed a negative potential of 150 volts, and continues over point 262, conductor 293, resistor 294 of 500,000 ohms, point 295, and resistor 296 of 500,000 ohms to the grid 292. The anode 297 is also given a negative potential of 150 volts before the starting relay is energized, which potential is obtained through a circuit from the point 295 in the grid circuit, over a resistor 298 of 500,000 ohms, point 299, and resistor 300 of 8,000 ohms.

When the starting relay 277 closes its contact 287, positive potential is applied to the anode 297 over a circuit which starts at the terminal 165, upon which is impressed a positive potential of 150 volts, and continues over conductor 166, point 301, conductor 302, contacts 287, point 303, resistor 304 of 250 ohms, point 305, conductor 306, point 299, and resistor 300. Point 305 in this circuit is connected to ground over a stabilizing capacitor of .1 microfarad. When the positive potential is applied to the anode 297 by the closing of the contacts 287, the circuit from point 299 to point 295 in the grid circuit causes the positive potential to be applied to the grid 292 and causes its potential to change from 150 volts negative to approximately ground potential. The application of positive potential by the closing of the contacts 287 has caused the anode 297 of the start tube to acquire a positive potential and the grid 292 to become more positive than 15 volts negative with respect to the cathode 289, which will cause the start tube 288 to fire and become conducting. Point 295 is connected to ground over a capacitor of .5 microfarad, which provides a slight delay in the firing of tube 288 after positive potential has been applied by the closing of contacts 287.

Resistor 291 in the cathode circuit will cause the potential of the cathode 289 to rise sharply when the tube becomes conducting, and this rise is utilized as the firing impulse for the first bank of symbol-transforming tubes. The firing impulse is derived from point 290, which is electrostatically coupled by capacitor 307 of .001 microfarad to the terminal 308, which terminal is connected to the terminal 309 (Fig. 1), to which the firing impulse conductor 130 for the first bank of symbol-transforming tubes is connected. Point

310 (Fig. 1) on the firing conductor 130 is connected to ground over resistor 311 of 15,000 ohms. Capacitor 307 and resistor 311 cooperate to sharpen the firing impulse, enabling the effect of the firing impulse to be removed from the control grids of the other tubes of the bank before the conduction in the previously "primed" tube is effective to cause the next tube in the sequence to be fired and rendered conducting in the normal manner, thus insuring substantially uniform intervals between the impulses of a burst.

After the transmission of the symbols has been initiated, the symbol-transforming banks will be operable one after another in sequence to generate impulses until the shift tube of the fifth bank has fired and become conducting. The potential rise of the cathode of this tube is utilized to fire a stop tube 315 (Fig. 6), which causes the termination of the transmission by energizing the stop relay 286 and thereby opening the holding circuit for the starting relay.

The cathode 316 of the stop tube 315 is at ground potential, being connected to ground over conductor 317. The grid 318 is given a negative biasing potential of approximately 34 volts by being connected to a potential supply circuit which extends from terminal 261, which is supplied with a negative potential of 150 volts, and continues over point 262, conductor 293, point 319, resistor 320 of 500,000 ohms, point 321, resistor 322 of 150,000 ohms to ground over conductor 317. The grid 318 is connected over resistor 323 of 50,000 ohms, point 324, and resistor 325 of 500,000 ohms to the point 321 in the potential supply circuit.

A circuit extends from point 324 over a capacitor 326 of 10 micro-microfarads to the terminal 327, which is connected to the terminal 328 (Fig. 5), to which the cathode of the shift tube is connected. This circuit enables the potential rise of the cathode of the shift tube of the fifth bank to reduce the bias of the grid 318, causing the stop tube to fire and terminate the operation of the sending apparatus.

The anode 329 of the stop tube 315 has positive potential applied thereto when contact 287 is closed by the starting relay. The circuit extends from the terminal 165 and over the contacts 287 to the point 303, as explained above, and then continues over resistor 330 of 500 ohms, point 331, the winding of the stop relay 286, and over resistor 332 of 10,000 ohms to the anode 329. Point 331 in this circuit is connected to ground over a stabilizing capacitor of .1 microfarad. Until the stop tube fires and becomes conducting, there will be no current in the circuit which includes the winding of the stop relay 286; however, as soon as the tube is fired and becomes conducting, current will flow through the winding of the stop relay 286, which will be energized and will open the contacts 284. The contacts 284 will break the holding circuit for the starting relay 277, which will be deenergized and will open contacts 285 and 287. Contact 285 will also interrupt the holding circuit for the starting relay 277 to prevent its reenergization when the contacts 284 close as the stop relay is deenergized. Contacts 287 open the anode circuit for the start and stop tubes, extinguishing these tubes and deenergizing the stop relay.

The operation of the stop tube, therefore, causes the termination of the operation of the sending apparatus and restores the starting controls to the condition which existed prior to the operation of the start key 276.

RECEIVING APPARATUS

The five bursts of negative potential impulses which are impressed on the signal output terminals 270 and 271 of the sending apparatus during a transmitting operation are transmitted to and impressed on signal input terminals 335 and 336 (Fig. 7) of the receiving apparatus.

The receiving apparatus, shown in Figs. 7 to 14 inclusive, accepts these bursts of impulses one after another and distributes them to different transforming and symbol-storing means. Each transforming and symbol-storing means consists of a group or bank of tubes, and the impulses are effective to selectively render one of the tubes of the group conducting, thereby to indicate and store the symbol which the number of impulses in the burst represents.

In order to set up a representation of the symbols which are received, the receiving apparatus contains a plurality of transforming and symbol-storing means consisting of groups or banks of symbol-representing and -storing tubes which are operable to transform the bursts of impulses into representations of the symbols; routing means which is operated after each burst of impulses has been received and is effective to route the successive bursts into different transforming and symbol-storing means; and a control impulse generating means which generates an impulse after each burst of impulses to cause the operation of the routing means.

Control impulse generating means

The bursts of negative impulses which are impressed on the input terminals 335 and 336 (Fig. 7) control the operation of a phase-changing vacuum tube 337, which converts them into bursts of positive impulses. The bursts of positive impulses from tube 337 are used to control an impulse-generating means to generate a control impulse after each burst of impulses has been received, and are also applied to a common impulse conductor 338 (Fig. 13) in the receiving apparatus, whence they are relayed selectively to the various banks of transforming and symbol-storing means in a manner to be described hereinafter.

The control impulse generating means is shown in Fig. 7 and includes a pair of vacuum tubes 340 and 341 connected to operate as a trigger pair; a slow-recovery control tube 342 for controlling the trigger pair; and a phase-changing and impulse-sharpening tube 343 controlled by tube 340 of the trigger pair for impressing an impulse on a firing impulse conductor 344 for the routing control device after each burst of impulses has been received.

Tube 340 of the trigger pair is normally conducting, and tube 341 is normally non-conducting; however, the first impulse of a burst is effective to render tube 341 conducting and tube 340 non-conducting. The impulses of a burst are also impressed on the control tube 342 and cause this tube to apply a bias on tube 340 as long as impulses of a burst are being received, which bias prevents the trigger pair from returning to its normal condition until the space occurs between bursts. When the trigger pair returns to its normal condition, tube 340 becomes conducting and controls the phase-changing and impulse-sharpening tube 343 to reduce conduction therein and thereby to cause a positive impulse to be impressed on the firing impulse conductor 344 for the routing control device.

The circuits described hereinbelow enable these tubes to function to produce a control impulse after each group of symbol-representing impulses has been received.

The phase-changing tube **337** is a zero-biased tube and is normally conducting. Anode **345** has a normal positive potential of 18 volts, which is derived from a positive potential of 150 volts applied at terminal **346**, over conductor **347**, point **348**, resistor **349** of 250 ohms, point **350**, and resistor **351** of 5,000 ohms. Point **350** is connected to ground over a stabilizing capacitor of .25 microfarad. The screen grid **352** has a potential of 105 volts applied thereto from terminal **353**, over conductor **354**, point **355**, resistor **356** of 500 ohms, and point **357**. Point **357** in this circuit is connected to ground over a stabilizing capacitor of 4 microfarads. The cathode **358** of this tube is connected directly to ground, and the control grid **359** is connected to ground over point **360** and resistor **361** of 25,000 ohms.

Point **360** in the circuit for control grid **359** is electrostatically coupled to input terminal **335** over capacitor **362** of 10 micro-microfarads, and, as the negative signal impulses are impressed on the terminal, they will cause the potential of the control grid **359** to become negative and reduce conduction in tube **337**.

Since tube **337** is normally conducting, its anode **345** will have a normal positive potential of about 18 volts due to the potential drop across resistors **349** and **351**, but, whenever a negative signal impulse is impressed on the control grid and stops conduction in the tube, the potential of the anode **345** will rise and provide a positive impulse. As explained earlier herein, the amplitude of the impulses which are transmitted is made large enough that variations in the amplitude of the impulses may occur during transmission, and the received impulse will still be effective to cut off conduction in the phase-changing tube **337**. A potential-tapping member **363** cooperates with resistor **351** and enables this potential rise, which occurs each time conduction ceases in tube **337**, to be utilized as a positive impulse for controlling the control impulse generating means, and also to be impressed on the common impulse conductor **338** (Fig. 13) in the receiving apparatus, whence it may be selectively relayed to various banks of transforming and symbol-storing means.

The connection from the potential-tapping member **363** to the common impulse conductor **338** extends over point **364** and terminal **365** (Fig. 7), which is connected to terminal **366** (Fig. 13), to which the common impulse conductor **338** is connected. The manner in which the positive impulses on conductor **338** are relayed to and are effective to operate the transforming and symbol-storing means will be explained hereinafter.

Conductor **367** (Fig. 7) extends from point **364** and enables the positive impulses to control the control impulse generating means.

The tubes **340** and **341** are connected to form a trigger pair in which tube **340** is normally conducting and tube **341** is normally non-conducting. Anode **370** of tube **341** has a positive potential of 150 volts applied thereto from point **371** on conductor **347**, over resistor **372** of 250 ohms, point **373**, resistor **374** of 5,000 ohms, and conductor **375**; and, since tube **341** is normally non-conducting, anode **370** will be at a positive potential of 150 volts. Point **373** in this circuit is connected to ground over a stabilizing capacitor of .25 microfarad. Screen grid **376** of tube **341** has a positive potential of 105 volts applied thereto from point **355** on conductor **354**, over resistor **377** of 500 ohms, point **378**, and conductor **379**. Point **378** in this circuit is connected to ground over a stabilizing capacitor of 4 microfarads. The suppressor grid **380** and cathode **381** of tube **341** are connected directly to ground.

The control grid **385** of tube **341** is given a normal negative bias by being connected to a circuit which starts at terminal **386**, upon which a negative potential of 150 volts is impressed, and continues to ground over conductor **387**, point **388**, resistor **389** of 30,000 ohms, and resistor **390** of 10,000 ohms, the connection of the control grid **385** to this circuit being over point **391**, resistor **392** of 25,000 ohms, point **393**, and potential-tapping member **394**, which cooperates with resistor **390** and is adjustable to enable the proper negative bias to be obtained on the control grid **385**. Point **393** in this circuit is connected to ground over a stabilizing capacitor of 10 microfarads. A further connection from point **391** in the control grid circuit extends over point **395** and capacitor **396** of 10 micro-microfarads to conductor **367**, upon which is impressed a positive impulse from tube **337** each time a signal impulse is received over input terminal **335**, and enables these positive impulses to be impressed on control grid **385**. The trigger connection between control grid **385** of tube **341** and the anode **397** of tube **340** extends from points **391** and **395**, over resistor **398** of 50,000 ohms in parallel with capacitor **399** of 50 micro-microfarads to point **400** in the anode potential supply circuit for tube **340**.

Tube **340** is normally conducting. Anode **397** has a normal positive potential of 20 volts derived from a positive potential of 150 volts applied from point **371** on conductor **347**, over resistor **372** and point **373**, and over resistor **401** of 5,000 ohms to points **402** and **400**. The screen grid **403** of tube **340** has a positive potential of 105 volts applied thereto by being connected at point **404** to conductor **379**, which also supplies this potential to the screen grid **376** of tube **341**.

Cathode **405** and suppressor grid **406** of tube **340** are connected directly to ground.

The control grid **407** of tube **340** is connected at point **408** to a circuit which starts at point **409** on the negative potential supply conductor **387** and continues over resistor **410** of 150,000 ohms, points **411** and **408**, resistor **412** of 100,000 ohms, and variable resistor **413** of 50,000 ohms to point **414**, and then to point **415**, to which the anode **420** of control tube **342** is connected. The anode **420** is normally at a positive potential of about 90 volts and causes the potential of the control grid **407** to be such that tube **340** will be conducting; however, when tube **342** has been rendered conducting and the potential of its anode **420** has dropped, this drop will cause the potential of the control grid **407** to become sufficiently negative to prevent conduction from occurring in tube **340**. The trigger connection between control grid **407** and the anode **370** of tube **341** extends from point **411** in the control grid circuit, over resistor **421** of 50,000 ohms and capacitor **422** of 50 micro-microfarads in parallel to points **423** and **424** on the conductor **375**, to which anode **370** of tube **341** is connected.

Control tube **342** is normally non-conducting but is rendered conducting each time a positive impulse occurs on conductor **367**.

In addition to the circuit traced earlier herein which extends to control grid **407** of tube **340**, the anode **420** of control tube **342** is also connected to ground over points **414** and **415** and capacitor 425 of 900 micro-microfarads, and is connected to conductor 347 over point 415, resistor 426 of 75,000 ohms, point 427, resistor 428 of 500 ohms, and point 371. Point 427 is connected to ground over a stabilizing capacitor of .1 microfarad. The screen grid 430 of the control tube 342 is connected to point 427 in the circuit between the anode 420 and the conductor 347. The cathode 431 of the control tube 342 is connected directly to ground.

The control grid 432 for the control tube 342 is given a negative bias by being connected to a circuit which starts from point 388 on the negative potential supply conductor 387 and continues to ground over resistor 433 of 50,000 ohms and resistor 434 of 10,000 ohms, the connection being over point 435, resistor 436 of 100,000 ohms, point 437, and an adjustable potential-tapping member 438, which cooperates with resistor 434 to enable the desired negative bias to be applied to the control grid. Point 437 in this circuit is connected to ground over a stabilizing capacitor of 10 microfarads, and point 435 is electrostatically coupled over capacitor 439 of 50 micro-microfarads and point 440 to conductor 367, which, as explained earlier herein, has a positive impulse impressed thereon each time a signal is received by the receiving apparatus.

Specifically, the operation and control of the tubes 340 and 341 of the trigger pair to produce control impulses are as follows.

When each symbol-representing impulse of a burst is impressed on the input terminal 335 of the receiving apparatus, it will cause the phase-changing tube 337 to be effective to impress a positive impulse on conductor 367. The first impulse of a burst on conductor 367 will be effective through capacitor 396 to reduce the bias on the control grid 385 of tube 341 and will render this tube conducting. When tube 341 becomes conducting, the potential of its anode 370 will drop, and this drop is effective through the trigger connection to render tube 340 non-conducting.

The first impulse on conductor 367 will also be effective, through capacitor 439, to reduce the bias on the control grid 432 of control tube 342 and render this tube conducting. When the control tube 342 becomes conducting, the potential of its anode 420 will drop, and, since the control grid 407 of tube 340 is connected to the anode 420, this potential drop will cause the potential of the control grid 407 to become sufficiently negative to prevent conduction from occurring in tube 340. The values for capacitor 425 and resistor 426 in the circuit with anode 420 are such that these elements will be effective to cause the potential of the anode to rise slowly after the momentary conduction in control tube 342, which was caused by the impulse, has ceased. The rise in anode potential is so regulated that the next impulse on conductor 367 is effective to render the control tube conducting again before the anode potential has recovered sufficiently to reduce the bias on control grid 407 to a point where tube 340 will become conducting. As the control tube 342 becomes conducting in response to the next impulse on conductor 367, the potential of the anode 420 will drop an amount equal to that which it had recovered after the previous conduction in tube 342 has ceased. Accordingly, the potential of the anode 420 will drop when the control tube 342 becomes conducting in response to the first impulse in a burst, and will fluctuate up and down as the successive impulses of the burst cause further conduction in the tube, but will not recover sufficiently during the receipt of a burst of impulses to enable the potential of the control grid 407 of tube 340 to acquire a value which will enable this tube to become conducting. During the time interval or space between successive bursts of impulses, however, control tube 342 will not be rendered conducting, and the potential of its anode 420 can recover sufficiently to be effective to reduce the bias on control grid 407 of tube 340, and that tube can be rendered conducting.

The adjustable resistor 413, which is included in the circuit between the anode 420 and the control grid 407, enables the selection of the point at which the potential rise of the anode 420 will cause the control grid 407 to lose control, and thus controls the maximum permissible interval that may occur between impulses of a burst without causing a control impulse to be generated.

As long as tube 340 remains non-conducting, it will be effective, through the trigger connection, to cause tube 341 to remain conducting between impulses; however, as tube 340 is rendered conducting during the interval between bursts, it will cause tube 341 to become non-conducting, and, as tube 341 becomes non-conducting, it will be effective through the trigger connection to cause a rapid rise in the rate of conduction in tube 340.

The potential of anode 397 of tube 340 will drop sharply as that tube becomes conducting, and will provide a negative impulse or control impulse after each burst of signal-representing impulses has been received. These control impulses are impressed on the control grid 450 of the phase-changing and impulse-sharpening tube 343, over point 402, capacitor 451 of 50 micro-microfarads, and point 452.

Thus it is seen that the tubes of the trigger pair are controlled to produce an impulse after each burst of symbol-representing impulses.

The phase-changing and impulse-sharpening tube 343 is normally conducting but is rendered non-conducting each time tube 340 becomes conducting. The anode 453 of tube 343 has a positive potential of 150 volts applied thereto by a circuit starting from point 348 on conductor 347 and continuing over resistor 454 of 250 ohms, point 455, and resistor 456 of 5,000 ohms. Point 455 in this circuit is connected to ground over a stabilizing capacitor of .25 microfarad. Although anode 453 has a positive potential of 150 volts applied thereto, it will have a normal positive potential of about 20 volts because of the drop across resistor 456. Screen grid 457 has a positive potential of 105 volts applied thereto over point 378 on conductor 379, which, as explained earlier herein, also supplies this potential to the screen grids of the tubes of the trigger pair. The suppressor grid 458 and cathode 459 of this tube are connected directly to ground, and its control grid 450 is connected to ground over point 452 and resistor 460 of 10,000 ohms.

When conduction is decreased in tube 343 as tube 340 becomes conducting, the potential of anode 453 will rise from its normal potential of 20 volts toward 150 volts, and this rise is impressed as a positive impulse on the firing impulse conductor 344 of the routing control device by means of a potential-tapping member 461, which cooperates with resistor 456 and is also connected to terminal 462, which is connected to terminal 463 (Fig. 16), to which the firing impulse conductor 344 is connected. The manner in which these impulses cause the routing control device to operate will be explained fully hereinafter.

Transforming and symbol-storing means

In the disclosed embodiment, the receiving apparatus contains five banks of transforming and symbol-storing means; however, the number of banks may be increased or decreased if desired. The five banks are shown in Figs. 8 to 12 inclusive and are given the reference numerals "I," "II," "III," "IV," and "V" to indicate the order in which they operate and the symbols which they will store. Since the circuits for the various banks are similar, the operation of all the banks will be clear from a description of one of the banks.

Referring to Fig. 8, which shows the bank for transforming the first burst of impulses into a single representation of a symbol and for storing this symbol, it is seen that a bank of transforming and symbol-storing means contains a plurality of gaseous electron tubes of the same type as those used in the sending apparatus. Of the plurality of gaseous electron tubes in the bank, there is a presetting tube "Preset," which is fired before reception takes place, and a symbol-representing tube for each of the digits "0" to "9" inclusive, although in this figure the tubes for the digits "3" to "6" inclusive have been omitted to simplify the showing of the bank, as their circuits are identical with those for the other tubes and an understanding of the operation of the bank can be had from the circuits shown.

The presetting tube "Preset" in the bank is fired before reception begins in the receiving apparatus, and is used to clear the bank of any previously stored symbol and to insure that the sequential firing of the tubes in a bank, in response to the impulses of a burst, will always begin with the same tube, which, in the instant embodiment, is the "0" tube.

The tubes in the bank are connected for sequential firing, beginning with the presetting tube, and thereafter the symbol-storing tubes for the digits from "0" to "9" inclusive, in that order, which, it will be noted, is the reverse order from the order in which the symbol transforming tubes in the sending apparatus are fired. The symbol-storing tubes are fired one after another in response to impulses relayed to a firing impulse conductor from the common impulse conductor 338 (Fig. 13). As each tube in the sequence is fired, it extinguishes any previously conducting tube, the last tube to be fired in any bank remaining conducting and serving to provide for the storage of a single representation of the symbol represented by the number of impulses in the burst.

The tubes which are conducting in the various banks at the end of a transmitting operation can be inspected to show directly the symbols stored in the various banks, can be used to control a remote indicating or recording apparatus, or can be used to transfer the symbols directly to other storing means.

The circuits for supplying the potentials and operative connections between the tubes of a bank are as follows:

Negative potential is supplied to the cathodes of the tubes of this bank (Fig. 8) by means of parallel circuits, one for each tube, extending to ground from a negative potential conductor 470, to which a negative potential of 150 volts is applied at terminal 471. The circuit for the "8" tube is representative and extends from the supply conductor 470 at point 472, over resistor 473 of 150,000 ohms, point 474, resistor 475 of 100,000 ohms, points 476, 477, and 478, and to ground over resistor 479 of 15,000 ohms in parallel with resistor 480 of 2,500 ohms and capacitor 481 of .002 microfarad in series. Cathode 482 of the "8" tube is connected to this circuit at point 477 and has a negative potential of approximately 9 volts when the tube is not conducting. When the tube is conducting, the potential of the cathode 482 will rise to a positive potential of about 48 volts.

The "9" tube, the last tube in the sequence, has a cathode potential supply circuit which is equivalent to the other circuits. This circuit extends from point 483 on the potential supply conductor 470, over resistor 484 of 150,000 ohms, resistor 485 of 100,000 ohms, points 486, 487, and 488, and to ground over resistor 489 of 15,000 ohms in parallel with a resistor 490 of 2,500 ohms in series with a capacitor 491 of .002 microfarad. Cathode 492 of the "9" tube is connected to this circuit at point 486.

The cathode potential supply circuits for all the tubes except the "9" tube are used to supply negative biasing potential for the control grids of the tubes next in the sequence, the connection being from the cathode circuit of one tube to the control grid of the next tube in the sequence. These connections enable the sequential firing of the tubes by utilizing the potential rise of the cathode of one tube to "prime" the next tube to be operated, so that the next tube may be fired and rendered conducting when the next impulse is impressed on the firing impulse conductor 495. The grid of the "9" tube, for instance, is connected over resistor 496 of 50,000 ohms, point 497, resistor 498 of 500,000 ohms, point 499, and conductor 500 to point 474 in the cathode potential supply circuit for the "8" tube, from which point it derives a normal negative biasing potential of about 65 volts when the "8" tube is not conducting. When the "8" tube becomes conducting and its cathode potential rises, it will cause the biasing potential of the grid of the "9" tube to be reduced to almost its critical point, so that the "9" tube can respond to the next firing impulse which is impressed on the bank. A capacitor 501 of 250 micro-microfarads connects point 499 in the grid circuit with point 476 in the cathode circuit to speed up the application of the potential rise on the grid of the "9" tube when the "8" tube becomes conducting.

The presetting tube "Preset," being the first tube in the series, does not have its control grid connected to the cathode potential supply circuit for another tube, but has a negative biasing potential of about 65 volts supplied thereto by an equivalent circuit extending from point 505 on the conductor 470, over resistor 506 of 120,000 ohms, points 507 and 508, and resistor 509 of 90,000 ohms to ground, to which the control grid 510 is connected at point 508.

The grids of the tubes in the sequence from the "0" tube to the "9" tube are electrostatically coupled to the firing impulse conductor 495 by means of capacitors of 10 micro-microfarads, as capacitor 511, by which point 497 in the grid circuit of the "9" tube is connected to the firing impulse conductor 495. The firing impulse conductor 495 extends from the terminal 512, and this terminal is connected to terminal 513 (Fig. 13) of the relay means which relays the impulses from the common impulse conductor 338 to this bank. The normal negative bias of the grids of these tubes is sufficient to render the firing impulses ineffective to cause the firing of the tubes; however, if any tube has been primed by the conduction in another tube in the sequence, the bias of the grid of the primed tube will have been reduced sufficiently that the firing impulse can cause that tube to fire and become conducting.

The anodes of the tubes of this bank are connected to a common anode supply conductor 515, which is connected over resistor 516 of 2,000 ohms, point 517, and resistor 518 of 250 ohms to terminal 519, which has a positive potential of 75 volts applied thereto. Point 517 is connected to ground over a stabilizing capacitor of .25 microfarad.

The presetting tube "Preset" is fired by a circuit which may be closed by any convenient means prior to the reception of data. For simplicity in the diagram, the circuit is shown closed by a presetting key 520. The circuit starts at terminal 521, upon which a positive potential of 150 volts is impressed, and continues over conductor 522, key 520, conductor 523, and resistor 524 of 120,000 ohms, to point 507 in the circuit for the control grid 510. When this circuit is closed by the key 520, it applies positive potential to the grid and causes its potential to become more positive than the cathode, which causes the tube to fire and become conducting.

The operation of the bank is as follows:

The presetting tube "Preset" is fired by momentarily depressing the presetting key 520 before reception of data takes place. The firing of this tube extinguishes any previously conducting tube in the bank and primes the "0" tube, so that the first impulse of the burst which is relayed to the firing impulse conductor 495 of the bank will cause the "0" tube to be fired and become conducting. The firing of the "0" tube will extinguish the preset tube, and conduction in the "0" tube will prime the "1" tube. The succeeding impulses of the burst will fire the tubes "1," "2," "3," and so on, depending upon the number of impulses in the burst. After the last impulse in the burst has fired a tube, that tube will remain conducting and will thereby store the symbol and provide a visual indication of the symbol which was represented by the burst. The conducting tube will be the only tube in the bank having its cathode at a positive potential, and conductors, as 525, extending from the cathodes of the symbol-representing tubes, can be sensed for this condition by any suitable means and can control a remote indicating or recording mechanism or can be used to control the direct transfer of the setting of the bank to another storage means.

The other banks for transforming and storing the second, third, fourth, and fifth symbols operate exactly as this bank. These banks are prepared by the presetting keys 526, 527, 528, and 529 (Figs. 9, 10, 11, and 12), which are operated momentarily before reception takes place and cause the presetting tubes to be fired. The circuits for firing the presetting tubes are shown closed by individual keys for simplicity in the showing of the circuits, but it is obvious that all these circuits could be closed by contacts of a single presetting relay or by some other similar construction.

The firing impulse conductors 530, 531, 532, and 533 for the "II," "III," "IV," and "V" banks (Figs. 9, 10, 11, and 12) are connected to terminals 534, 535, 536, and 537, which terminals are connected to terminals 538, 539, 540, and 541, respectively (Fig. 13), of the relay means for the various banks.

As the relay means for the various banks become operative one after another to relay impulses to the firing impulse conductors, the tubes in the various banks will be fired in sequence, and, at the end of the receiving operation, the bursts of impulses will have been transformed into single representations of the symbols and those tubes in the several banks will be conducting which correspond to the symbols set up on the keys in the sending apparatus.

Routing means

Routing means, consisting of relay means and a routing control device, are provided in the receiving apparatus to route the successive bursts of impulses into the different banks of transforming and symbol-storing means.

A plurality of relay means, one for each bank of transforming and symbol-storing means, are used to selectively relay the impulses from the common conductor 338 to the firing impulse conductors of different banks of transforming and symbol-storing means. The several relay means are normally unresponsive to the impulses on the common impulse conductor 338 but can be successively "primed" or made responsive under control of the routing control device, so that different relay means will be responsive to the successive bursts of impulses, and can cause the successive bursts of impulses to control the setting of the symbols in the various banks.

The routing control device (Fig. 14) includes a control tube for each relay means, and these control tubes, which are gaseous electron tubes of the same type as those used in the sending apparatus, are connected for sequential step-by-step operation each time a control impulse is impressed on the routing control device. As each control tube is fired and becomes conducting, it extinguishes any previously conducting control tube of the device; primes its related relay means to render it effective to relay impulses from the impulse conductor 338; and primes the next control tube in the sequence so that it will fire and become conducting when the next control impulse is impressed on the routing control device.

Inasmuch as a control impulse is generated in the receiving apparatus after each burst of impulses has been received, it is necessary to fire the control tube for the first bank before the first burst is received. The firing of the first control tube will extinguish any previously conducting control tube which might have remained conducting from a previous operation of the device, and insures that the first burst of impulses will be entered in the first bank of transforming and symbol-storing means.

The routing control device is shown in Fig. 14, in which the control tubes are given the reference numerals "I," "II," "III," "IV," and "V" to indicate with which of the burst they are operative. As the circuits for the various control tubes of the routing control device are similar, it is believed that the operation of the device will be clear from a description of representative circuits.

Potential is supplied to cathode 545 of the "I" control tube by a circuit which has two branches, one of which is also utilized to supply a negative biasing potential for the relay means related to the "I" control tube, and the other of which is also utilized to supply negative biasing potential to the control grid 546 for the "II" control tube. The one branch extends from a negative potential supply conductor 547, to which a negative potential of 150 volts is applied at terminal 548, and continues over point 549, resistor 550 of 300,000 ohms, point 551, and resistor 552 of 150,000 ohms to points 553, 554, and 555. The other branch extends from the potential supply conductor 547 at point 556 and continues over resistor 557 of 300,000 ohms, point 558, and resistor 559 of 200,000 ohms to the points 554 and 555. From the points 554 and 555, the two branches continue to ground over resistor 560 of 15,000 ohms in parallel with resistor 561 of 2,500 ohms and capacitor 562 of .002 microfarad in series. The cathode 545 is connected at point 554 in this circuit and is given a negative potential of approximately 7 volts whenever the tube is not conducting. When the tube is conducting, the electron discharge therein enables a positive potential applied to the anode to be applied to the cathode and will cause the potential of the cathode to rise to a positive potential of about 48 volts.

A circuit extends from point 551 in said one branch and continues over conductor 542, point 543, conductor 563, and terminal 564, which is connected to terminal 565 (Fig. 13) and supplies a negative biasing potential of about 55 volts to the relay means for the first bank of transforming and symbol-storing means. This circuit also enables the potential rise of the cathode 545, due to conduction in the control tube, to be used to reduce the negative bias or "prime" the relay means.

A capacitor 566 of 50 micro-microfarads is connected between points 553 and 543 to cause the change in potential to be applied rapidly when the relay means is primed by the potential rise of the cathode.

A circuit extends from said other branch of the cathode potential supply circuit at point 558 and continues over resistor 567 of 500,000 ohms, point 568, and resistor 569 of 50,000 ohms to grid 546 of the "II" control tube to supply this grid with a normal negative potential of about 64 volts. This circuit enables the "II" tube to be primed by having this negative potential reduced almost to the critical point by the potential rise of cathode 545 when the "I" tube is conducting.

Grid 546 of the "II" tube is connected over point 568 and capacitor 570 of 10 micro-microfarads to the impulse conductor 344, which is connected to terminal 463, upon which is impressed a positive impulse by the control impulse generating means after each burst of impulses had been received. These positive impulses will be able to fire only that tube of the bank which has been primed.

The "I" tube is the first tube in the sequence, and its grid cannot derive its negative bias from the cathode potential supply circuit of a preceding tube. A circuit extending from point 571 on conductor 547 and over resistor 572 of 150,000 ohms, point 573, and resistor 574 of 100,000 ohms to ground supplies grid 575 with a negative biasing potential of about 60 volts over point 573 and resistor 576 of 500,000 ohms.

Since the routing control tubes are fired in response to control impulses which are generated after the bursts have been received, the "I" routing control tube must be fired from a different source before the first burst is received, in order that the relay means for the first transforming and symbol-storing bank can be primed and will respond to all the impulses of the first burst. This may be accomplished in any convenient manner; for instance, a presetting key 577 (Fig. 14) can be momentarily depressed to close a circuit starting from terminal 578, upon which a positive potential of 150 volts is impressed, and continuing over the key 577, resistor 579 of 150,000 ohms to point 573 in the circuit of grid 575. The application of this positive potential to the grid 575 will reduce the negative bias of the grid sufficiently to cause the tube to fire and become conducting, thereby rendering the relay means for the first bank of transforming and symbol-storing means operative and preparing the "II" routing control tube for firing in response to the control impulse which is generated after the first burst of impulses has been received. The circuit closed by key 577 may be closed by a presetting relay along with the presetting circuits of the transforming any symbol-storing banks, as explained earlier herein.

Potential is applied to the anode 580 of the "II" tube by means of a circuit starting at terminal 581, upon which is impressed a positive potential of 75 volts, and extending over resistor 582 of 250 ohms, point 583, resistor 584 of 2,000 ohms, and conductor 585, to which anode 580 is connected. The anodes of the other tubes are also connected to conductor 585, and, when none of the tubes is conducting, the potential of the anodes will be 75 volts, but, when any tube is conducting, this potential is reduced to about 65 volts due to the resistors 582 and 584. Point 583 in this circuit is connected to ground over a capacitor of 8 microfarads to absorb the shock of an abrupt application of or change in potential in this circuit. The common resistance in the anode potential supply circuit enables the firing of any tube of the routing control device to extinguish conduction in any previously conducting tube in the device in the manner explained earlier herein.

From the above descripetion, it is clear that the control tubes in the routing control device will be fired one after another as the control impulses are generated after the successive bursts are received, and will prime the relay means for the several banks one after another in succession.

The relay means are shown in Fig. 13 and consist of a pair of vacuum tubes for each transforming and symbol-storing bank, which relay means have been given the reference numerals "I," "II," "III," "IV," and "V" to indicate with which bank of transforming and symbol-storing tubes they are related, and also to indicate the order in which they operate. A description of the relay means shown at "I" in Fig. 13 will be given, and, as the relay means for the other banks are similar, it is believed that an understanding of these means and their operation will be clear from this description.

Tubes 590 and 591, which constitute the means for relaying impulses from the common impulse conductor 338 to the first bank of transforming and symbol-storing tubes, are normally inoperative to relay the positive impulses from the common impulse conductor 338, because the control grid 592 of tube 590 is normally given a negative bias which the positive impulses cannot overcome. The tube 590 is "primed" by having the negative bias of its grid 592 reduced, and in this condition the tube can respond to the positive potential impulses on the common impulse conductor 338 and can cause the impulses to be relayed to the firing impulse conductor 495 for the first bank of transforming any symbol-storing tubes.

The cathode 593 of tube 590 is connected directly to ground. The anode 594 of this tube is given a positive potential of 150 volts over a circuit starting at terminal 595, upon which is impressed a positive potential of 150 volts, and continuing over potential supply conductor 596, point 597, resistor 598 of 500 ohms, points 599 and 600, resistor 601 of 5,000 ohms, and point 602 to the anode 594. The screen grid 603 is given a normal positive potential of 150 volts by being connected to point 600 in the above anode circuit. Suppressor grid 604 is directly connected to ground.

The control grid 592 is connected over point 605 and resistor 606 of 10,000 ohms to terminal 565, which, as explained before, is given a negative biasing potential of about 45 volts from one branch of the cathode potential supply circuit for the "I" routing control tube. The control grid 592 is also connected electrostatically to the common impulse conductor 338 from point 605 over a capacitor 607 of 100 micro-microfarads. The potential on the grid 592 is normally sufficiently negative that the tube 590 is not responsive to the positive potential impulses on the impulse conductor 338, but, when the "I" control tube of the routing control device is conducting, the potential rise of its cathode 545 will reduce the negative potential of grid 592, or "prime" the tube 590 so that it will be capable of responding to the impulses on conductor 338 and become conducting each time an impulse occurs on that conductor.

Whenever tube 590 becomes conducting, the potential of its anode 594 will drop due to the resistors 598 and 601 in its anode potential supply circuit, and, through an electrostatic connection from point 602 in this circuit over capacitor 608 of 100 micro-microfarads and point 609, this drop is applied as a negative potential impulse on control grid 610 of the phase-changing and amplifying tube 591.

Tube 591 is a zero-biased tube and is normally conducting. This tube has its cathode 611 directly connected to ground; its screen grid 612 connected over point 613 and resistor 614 of 500 ohms, point 615, and conductor 616 to terminal 617, to which is applied a positive potential of 105 volts; and its control grid 610 connected to ground from point 609 over resistor 618 of 10,000 ohms, and also electrostatically connected to the anode 594 of tube 590, as explained above.

The anode 620 of the phase-changing and amplifying tube 591 is connected over resistor 621 of 5,000 ohms, point 622, and resistor 623 of 250 ohms to point 624 on the potential supply conductor 596, which is connected to terminal 595, to which is applied a positive potential of 150 volts. Point 622 in this circuit is connected to ground over a stabilizing capacitor of .25 microfarad. As this tube is normally conducting, anode 620 will normally have a potential of about 16 volts, but, whenever a negative potential impulse is impressed on the control grid, conduction in the tube will be reduced and the potential of the anode will rise. A potential-tapping member 625 cooperates with resistor 621 to enable this rise to be utilized as a positive potential impulse which is impressed on the firing impulse conductor 495 of the first bank of transforming and symbol-storing means to cause the firing of the tubes in that bank. The connection from the potential-tapping member 625 to the firing impulse conductor extends from the potential-tapping member 625 over conductor 626 to terminal 513, which, as explained above, is connected to terminal 512 (Fig. 8), to which the firing impulse conductor 495 is connected.

The other relay means will, when effective, relay impulses from the common impulse conductor 338 to the firing impulse conductors of their respective banks.

Terminals 627, 628, 629, and 630 (Fig. 14), which are connected to terminals 631, 632 633, and 634, respectively (Fig. 13), supply biasing potential to the various relay means and enable the "II," "III," "IV," and "V" tubes of the routing control device to prime the relay means one after another to enable the bursts of impulses to be routed to the proper banks of transforming and symbol-storing means.

As explained earlier herein, terminal 538 (Fig. 13) is connected to terminal 534 (Fig. 9), to which the firing impulse conductor 530 for the second bank is connected, and enables the relay means to impress as many firing impulses on this conductor as there are impulses in the second symbol-representing burst of impulses impressed on conductor 338.

Similarly, terminals 539, 540, and 541 (Fig. 13) are connected to terminals 535, 536, and 537 of Figs. 10, 11, and 12, respectively, to enable the third, fourth, and fifth bursts of impulses to be relayed to the firing conductors 531, 532, and 533 of their respective banks of transforming and symbol-storing means.

Thus, by the operation of the routing means, the successive bursts of impulses which are received are automatically sent to the proper banks of transforming and symbol-storing means, where the bursts are transformed into single representations of the various symbols and are stored.

Operation

In the operation of the novel communication system, the keys of the sending apparatus are depressed according to the symbols to be sent. The keys, which in the instant embodiment correspond to the digits 1 to 9 inclusive, are effective to prime related tubes in the banks of impulse-generating tubes to control with which tube the sequential firing of the tubes of a bank will begin. In any bank in which no key has been depressed, the "0" tube is automatically selected.

After the keys in the various banks have been depressed to set up the symbols to be transmitted, a start key is operated to initiate the generation of the bursts of impulses. The operation of the start key initiates the sequential firing of the tubes of the first bank to generate the impulses of the first burst, and, when the "0" tube is fired to generate the last impulse of the bursts, it causes the shift tube to be fired after a slight delay. The firing of the shift tube initiates the sequential firing of the tubes in the second bank to generate a second burst of impulses, which are separated from the first burst by a space or time interval. In a like manner, the tubes of the third, fourth, and fifth banks of tubes will be operated in succession to produce spaced bursts of impulses containing the desired number of impulses as determined by the setting of the keys of the keyboard. The impulses which are generated by the several banks of tubes form an impulse train containing a plurality of spaced bursts of similar negative impulses having like significance, which impulses are generated at a high rate of speed and are sent out one after another over a single communication channel to the receiving apparatus. With the values given herein for the resistors and capacitors in the various circuits, the impulses are generated at a rate of about 40 kilocycles and the time interval between bursts is about 150 micro-seconds.

The receiving apparatus is "preset" or prepared for reception by firing, in any convenient manner, a "presetting" tube in each of the plurality of banks of transforming and symbol-storing tubes and by firing the first control tube of the routing control device. This presetting operation clears the receiving apparatus of any symbols which remained therein from a previous operation, and conditions the routing control device to "prime" the relay means for the first bank of transforming and symbol-storing tubes so that the first burst of impulses will be routed to that bank.

The receiving apparatus, being controlled by the number of signals received, is not critical as to their form, so that slight variations in the signal strength which may occur during transmission will not be effective to cause erroneous reception of the data transmitted. This condition eliminates the necessity of preserving the exact signal form in transmission and enables the system to operate reliably without being excessively critical.

The negative impulses which are impressed on the receiving apparatus are changed to positive impulses by a phase-changing tube, which passes them to the relay means for the various banks of transforming and symbol-storing means and also passes the impulses to the control impulse generating means to cause this mean to generate a control impulse after each burst of impulses has been received.

The control impulse generating means contains a pair of tubes connected as a trigger pair, in which one of the tubes is normally conducting as long as no impulses are being received, and contains a slow-recovering control tube which is effective to prevent the normally conducting tube from returning to conducting condition as long as the impulses of a burst are being received. The first impulse of a burst is operative to reverse the state of conductivity of the tubes of the trigger pair and also to operate the slow-recovery control tube which prevents the trigger pair from returning to normal condition after the first impulse has ceased to control. The control tube is affected by each impulse of a burst, and its recovery is sufficiently slow that it will maintain the trigger pair in its operated state as long as impulses of a burst are received. The control tube will recover during the time interval between bursts, however, and allow the tubes of the trigger pair to resume their normal state of conductivity. As the normally conducting tube of the trigger pair resumes its conducting condition, it is effective to generate a control impulse, which is impressed on a routing control device to cause an operation of the device.

The routing control device, as it operates, is effective to render the relay means for the various banks of transforming and symbol-storing means operable one after another to enable the various bursts to be relayed to the proper banks of transforming and symbol-storing tubes.

The impulses which are relayed to the various banks of transforming and symbol-storing means will cause the step-by-step operation of the tubes of the banks to transform the different numbers of impulses in the bursts into single representations of the symbols, so that, at the end of the receiving operation, those tubes which have been fired and remain conducting in the various banks will correspond to the keys which were set in the sending apparatus and will provide an indication of the symbols making up the data which has been transmitted and received.

In applicants' novel communication system, therefore, the symbols are transformed into spaced bursts of different numbers of rapidly recurring like impulses and are transmitted without allocation control impulses to a receiving apparatus. The receiving apparatus generates a control impulse after each burst of symbol-representing impulses and is controlled jointly by the symbol-representing impulses and the control impulses to properly allocate the symbol-representing impulses and to transform the different numbers of symbol-representing impulses back into direct representations of the symbols. Since all the signals are alike and have the same significance, the system has the further advantage that it is not necessary to maintain a distinction between the various signals, and slight variations in the signals can be permitted without affecting the accuracy of the transmission of data.

Due to the fact that relatively small numbers of impulses are used to represent the symbols, and due to the fact that the impulses are generated at the supersonic frequency of about 40 kilocycles, the impulse train by which data is transmitted is of such short duration that unauthorized interception of the data is extremely difficult.

The claims of this application are directed to a communication system. A divisional application, Serial No. 596,751, filed May 30, 1945, now U. S. Patent 2,428,089 of Sept. 30, 1947, contains claims to the sending apparatus, per se, while another divisional application, Serial No. 596,752, filed May 30, 1945, contains claims to the receiving apparatus per se.

While the form of the invention herein shown and described is admirably adapted to fulfill the objects primarily stated, it is to be understood that it is not intended to confine the invention to the one form or embodiment herein disclosed, for it is susceptible of embodiment in various forms all coming within the scope of the claims which follow.

What is claimed is:

1. In a communication system in which different numbers of signals are assigned to represent different symbols which may be transmitted and which comprises a sending station and a receiving station, the combination of means at the sending station for generating uniformly spaced bursts of different numbers of substantially identical signals according to the symbols being transmitted, which signals of a burst follow each other at a supersonic frequency; means to transmit the bursts of signals one after another over a single communication channel to the receiving station, with a uniform space or time interval between bursts; a plurality of means at the receiving station, responsive to the number of supersonic signals in the various bursts as they are received, and controlled solely by the number of signals, to set up direct representations of the symbols to which the different numbers of signals have been assigned; and means responsive to the signals in the bursts, and operated during the time interval between bursts, for routing the bursts to different ones of said plurality of means to cause the operation thereof to set up the symbols.

2. In a communication system in which different numbers of signals are assigned to represent different symbols which may be transmitted and which comprises a sending station and a receiv-

ing station, the combination of electronic means at the sending station for generating uniformly spaced bursts of different numbers of rapidly recurring signals, which signals of a burst follow each other at a supersonic frequency and correspond in number to that assigned to represent the symbol being transmitted, said signals being substantially identical and consisting of impulses having an amplitude which is greater than that necessary to cause an operation of the means at the receiving station so that slight variations in amplitude which may occur in the signals during transmission will not cause erroneous reception thereof; means to transmit the bursts of signals one after another over a single communication channel to the receiving station, with a uniform space or time interval between bursts; a plurality of electronic means at the receiving station, responsive in a like manner to each of the supersonic signals in the various bursts as they are received, and controlled solely by the number of signals in the bursts, to set up direct representations of the symbols to which the different numbers of signals have been assigned; and electronic means responsive in a like manner to each of the supersonic signals in the bursts, and operated during the time interval between bursts, for routing successive bursts to different ones of said plurality of means to cause the operation thereof to set up the symbols.

3. A communication system in which different numbers of signals are assigned to represent different symbols which may be transmitted and which comprises a sending station and a receiving station; means at the sending station to set up a plurality of symbols to be transmitted; electronic means at the sending station controlled by the set means for generating the desired numbers of signals at a supersonic frequency, thereby transforming the symbols one after another automatically into uniformly spaced bursts of different numbers of rapidly recurring signals according to symbols being transmitted, the signals of each burst following each other at supersonic frequency; means to transmit the spaced bursts of signals one after another over a single communication channel to the receiving station, with uniform spacing between bursts; a plurality of differentially operable electronic means at the receiving station, each means being differentially responsive to the number of supersonic signals in a different one of the bursts,, and the plurality of means being controlled solely by the number of signals to transform the signals into direct representations of the symbols to which the different numbers of signals in the bursts have been assigned and provide a representation of these symbols; routing means at the receiving station to enable the successive bursts of signals to control the various ones of the plurality of means in succession; and means controlled by the signals of a burst for generating a control signal after the burst has been received, said control signal causing the routing means to operate and cause the next burst to be routed to the next of the plurality of means in the succession, whereby the symbols will be represented at the receiving station in the same order in which they were set up at the sending station.

4. In a communication system in which different symbols which might be transmitted from a sending station to a receiving station are represented by different assigned numbers of impulses and not by variations in the impulses per se, the combination of impulse-generating means at the sending station, said generating means including banks of electronic devices, which banks are differentially operable to transform the symbols to be sent, into spaced groups of rapidly recurring substantially identical signal impulses having supersonic frequency and having an amplitude greater than that necessary to cause an operation of input means at the receiving station; means to transmit the groups of signal impulses as they are formed, one group after another, over a single communication channel from the sending station to the receiving station; electronic input means at the receiving station completely responsive to supersonic impulses of smaller amplitude than sent thereto so that proper operation of the receiver will be insured regardless of possible variations which might occur in the amplitude of the signal impulses during transmission, said input means responding in the same manner to each signal impulse impressed thereon and producing an impulse each time it responds to a signal impulse; a plurality of electronic means for transforming the different numbers of impulses back into direct representations of the symbols and storing these symbols; electronic means for selectively routing the different groups of impulses produced by the input means to various ones of the transforming and symbol-storing means to cause their differential operation; and control impulse generating means including electronic devices controlled by the impulses from the input means and operated to generate a control impulse during the space between groups of impulses, which impulses cause the routing means to operate and direct the next group of impulses to another transforming and symbol-storing means.

5. A communication system in which each of the symbols making up data which may be transmitted is represented by a burst containing a preassigned number of similar supersonic impulses, said system including a sending station and a receiving station; presettable means at the sending station for setting up a plurality of symbols to be transmitted; electronic means at the sending station, controlled by said presettable means according to the setting thereof and operating to generate bursts of impulses at a supersonic frequency, to transform the plurality of symbols, one after another, automatically into uniformly spaced bursts of supersonic impulses, each burst containing the preassigned number of similar impulses according to the symbol being transmitted; means to transmit the bursts of impulses as they are generated, one after another, over a single communication channel from the sending station to the receiving station; a plurality of differentially operable electronic means at the receiving station, each of the differentially operable electronic means being responsive to the supersonic impulses of a burst of impulses generated by the electronic means at the sending station and operating to set up a direct representation of the symbol corresponding to the number of impulses in the burst; electronic switching means at the receiving station upon which the bursts of impulses are impressed, said switching means being selectively operable by special control impulses to switch the burst of impulses, as they are received, to the various ones of the plurality of differentially operable electronic means; and further electronic means at the receiving station controlled by the supersonic impulses of a burst and operable, during the space between bursts, to generate the special control

impulses for causing the operation of the switching means.

6. A communication system in which data may be transmitted rapidly by preassigning numbers of supersonic impulses to represent the various symbols which may be used to make up the data, said system including a sending station and a receiving station; a plurality of groups of electron discharge devices at the sending station, each of which devices generates an impulse when operated; means interconnecting the devices of each of the groups for automatic sequential operation to generate impulses at supersonic frequency; means interconnecting the groups of devices for operation automatically, one group after another, with a predetermined time interval between the operation of successive groups; manipulative means at the sending station for setting up a plurality of symbols to be transmitted and for controlling the electron discharge devices of the groups to control the number of devices which will operate in the various groups to produce the bursts of impulses having numbers of impulses corresponding to the preassigned number of impulses required to represent the several symbols which are set up; means to transmit the bursts of impulses over a single communication channel from the sending station to the receiving station; a plurality of groups of electron discharge devices at the receiving station, said groups of electron discharge devices at the receiving station being normally inoperative; means connecting the electron discharge devices within each group at the receiving station for operation one at a time in sequence in response to the supersonic impulses when the group is operative, whereby to set up direct representations of the symbols corresponding to the number of impulses in the various bursts; control means at the receiving station, which control means is preset to render one group of electron discharge devices at the receiving station operable by the first burst of impulses to be

received and is operated by control impulses to render the other groups operable in succession; and means at the receiving station, controlled by the symbol-representing impulses and operable to generate a control impulse during the interval between bursts, to cause the control means to automatically render another group of electron discharge devices operable as each of the bursts is received.

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Certificate of Correction

Patent No. 2,451,859. October 19, 1948.

ROBERT E. MUMMA ET AL.

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows:

Column 12, line 19, for "reruced" read *reduced*; column 26, line 63, for the word "burst" read *bursts*; column 27, line 54, for "had" read *has*; column 28, lines 17 and 73, for "any" read *and*; same column, line 20, for ' "II" tube' read *"I" tube*; line 40, for "descripetion" read *description*;

and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 15th day of February, A. D. 1949.

THOMAS F. MURPHY,
Assistant Commissioner of Patents.