April 5, 1949. R. E. MUMMA ET AL 2,466,467

COMMUNICATION SYSTEM

Original Filed Feb. 25, 1943 8 Sheets-Sheet 1

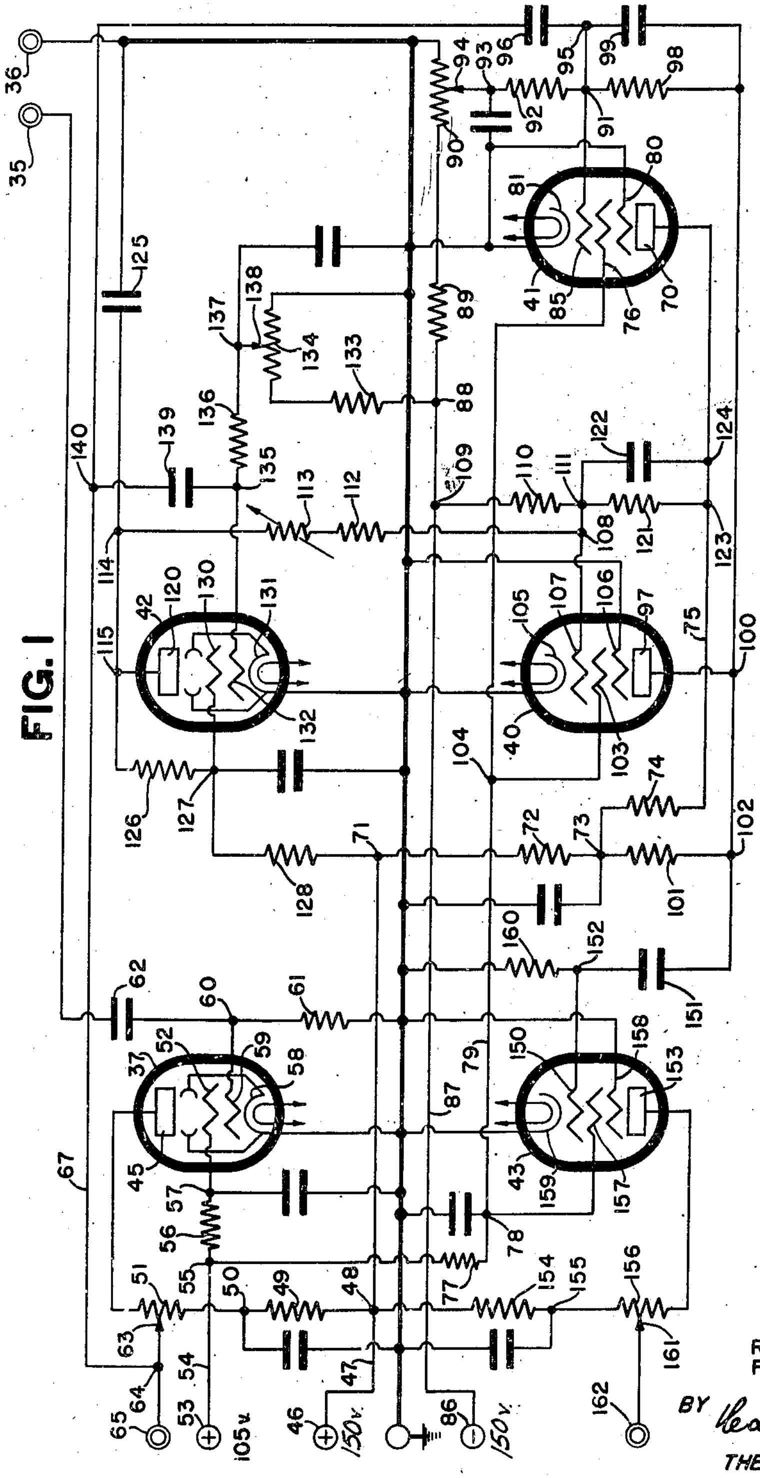

FIG. 1

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COMMUNICATION SYSTEM

Original Filed Feb. 25, 1943 8 Sheets-Sheet 2

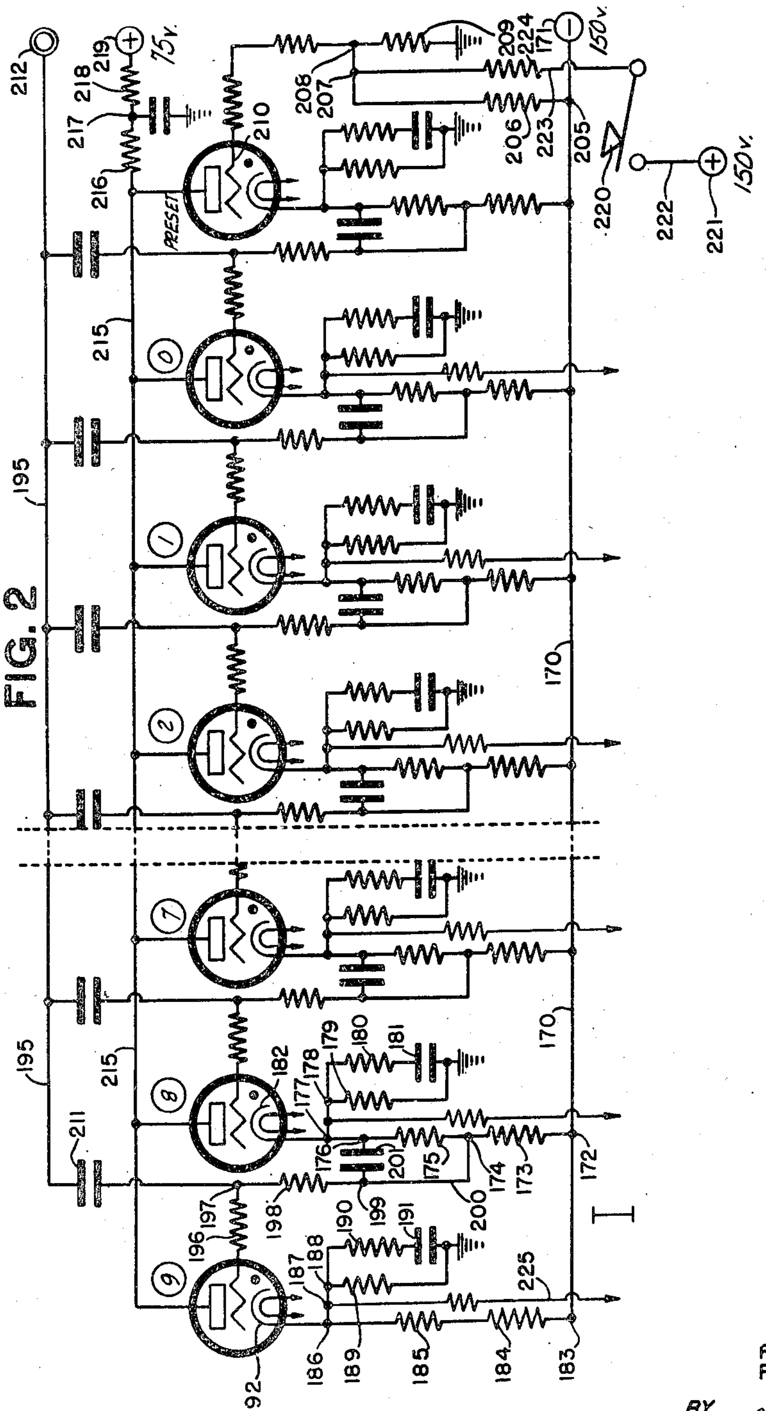

FIG. 2

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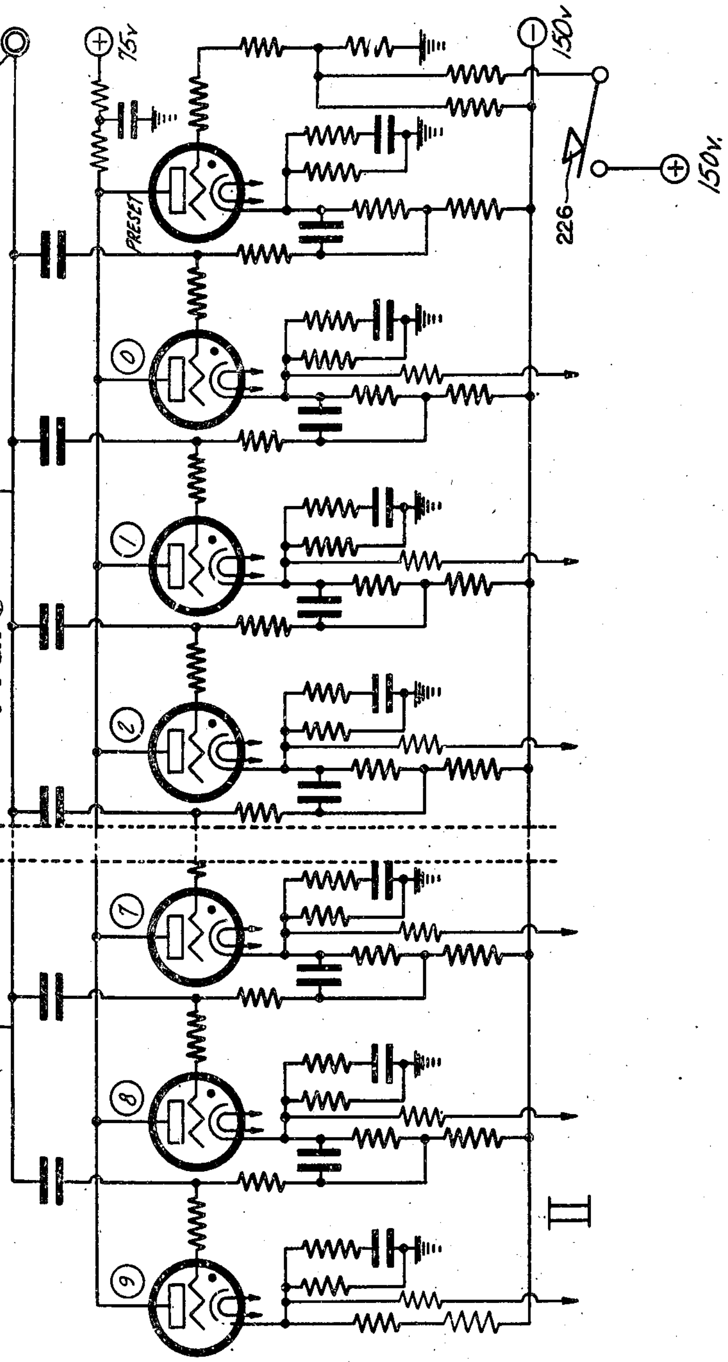
FIG. 3



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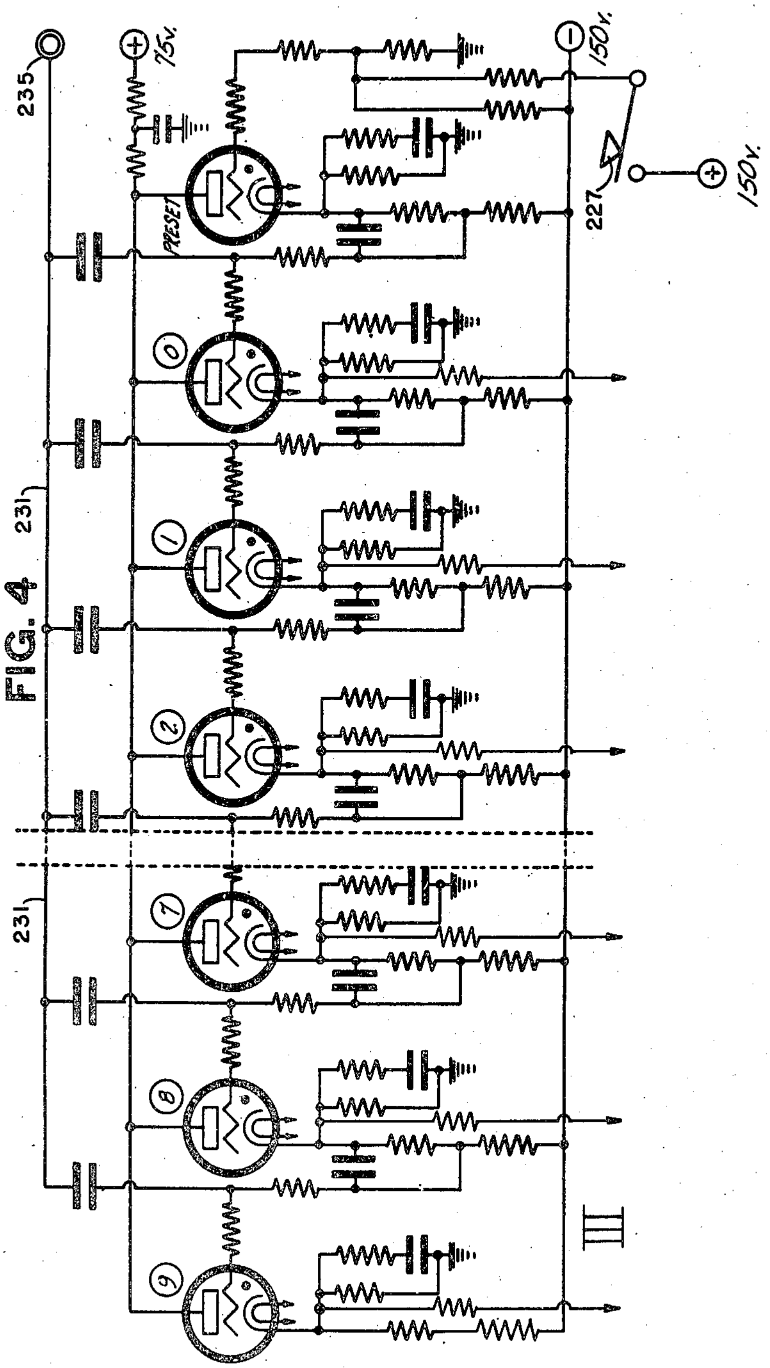

FIG. 4

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COMMUNICATION SYSTEM

FIG. 5

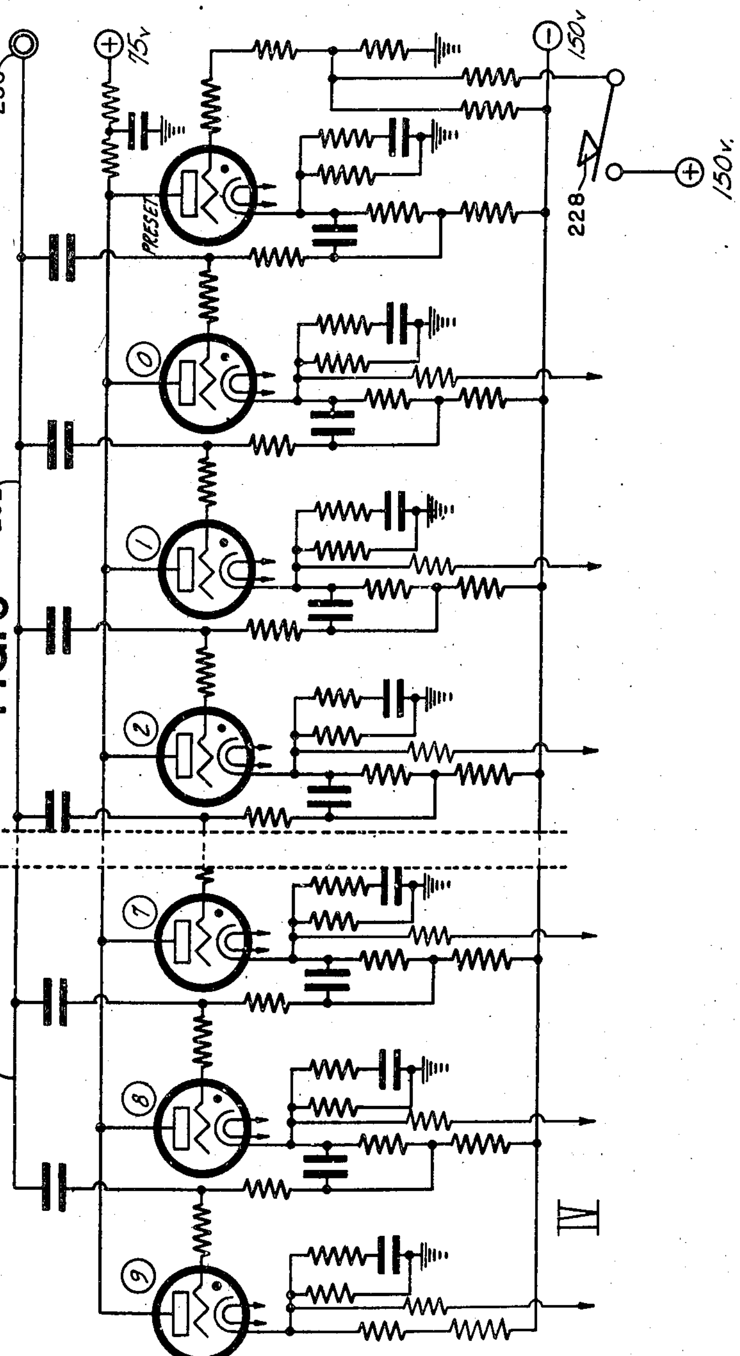

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FIG. 6

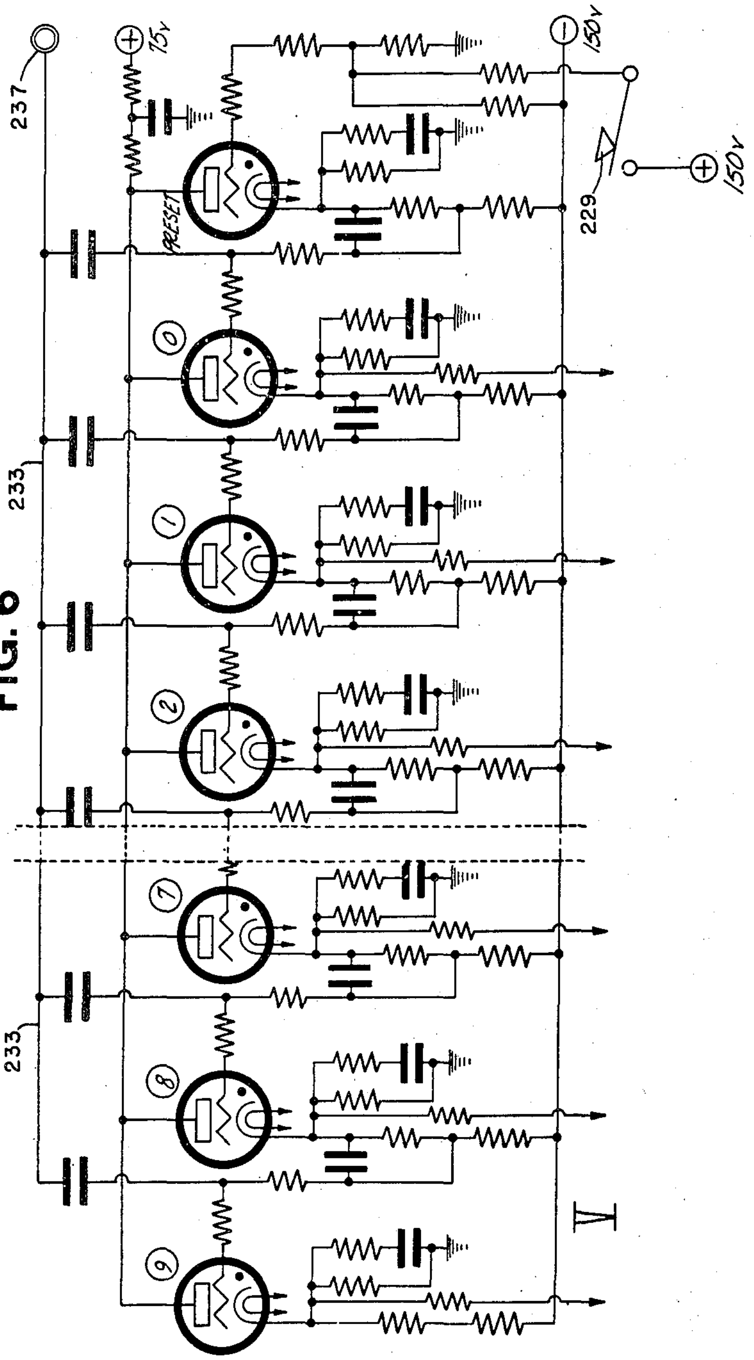

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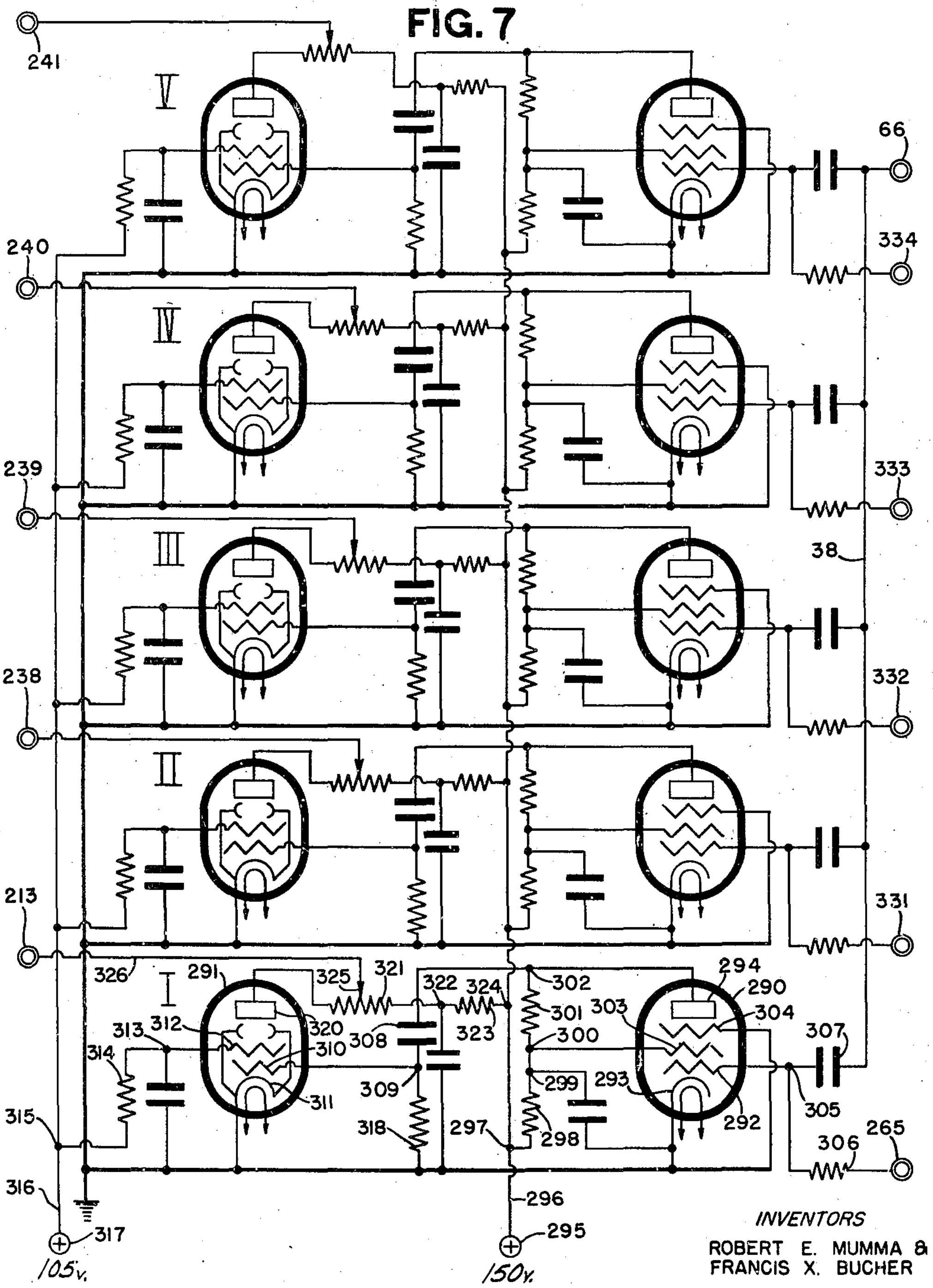
FIG. 7



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COMMUNICATION SYSTEM

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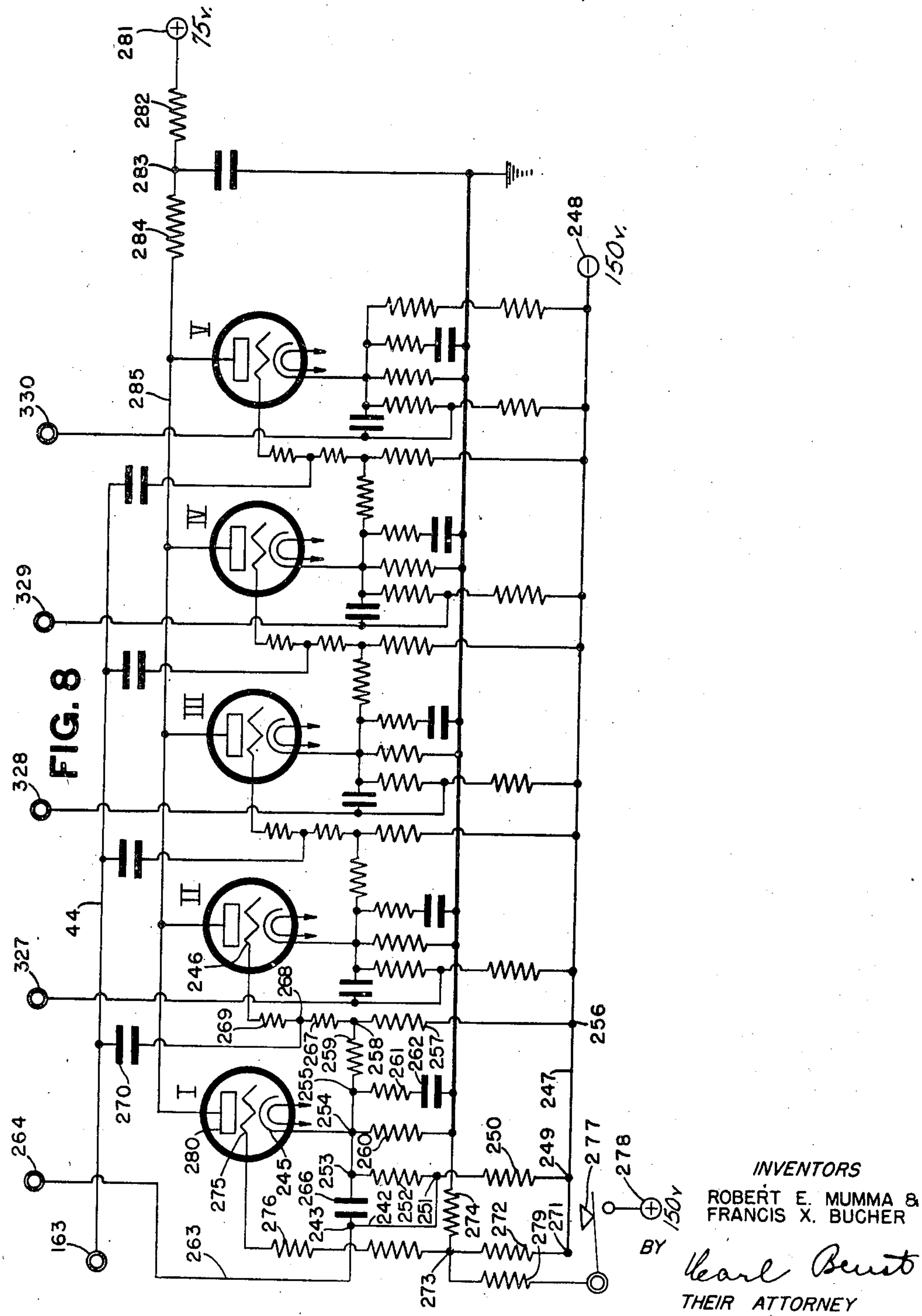
FIG. 8



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Patented Apr. 5, 1949 2,466,467

UNITED STATES PATENT OFFICE

2,466,467

COMMUNICATION SYSTEM

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Original application February 25, 1943, Serial No. 477,096, now Patent No. 2,451,859, dated October 19, 1948. Divided and this application May 30, 1945, Serial No. 596,752

11 Claims. (Cl. 177—353)

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This application is a division of applicants' copending application Serial No. 477,096, which was filed on February 25, 1943, now U. S. Patent 2,451,859 granted October 19, 1948.

This invention relates to communication systems and is directed particularly to a receiving apparatus for use in 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

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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.

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 receiving station can 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 high-speed means for receiving data in the form of bursts of different numbers of substantially identical signals.

A further object of the invention is to provide a novel receiving apparatus which can respond accurately to signals transmitted thereto at a high frequency and can set up a direct representation of data represented by the signals.

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 controlled signals to route the different burst 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 means for receiving the bursts of impulses and for creating an impulse to control a routing means after each burst is received.

Figs. 2, 3, 4, 5, and 6 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. 7 shows relay means for selectively directing or routing impulses to the various groups of transforming and symbol-storing means.

Fig. 8 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 received by the novel receiving 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 receiving five symbols in succession and is arranged to receive 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 a 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, because the invention is capable of being carried out by using other equivalent arrangements.

The novel 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. 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 indicated 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.

It is to be understood that the capacity of the receiving apparatus is not 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 receiving apparatus for reliably and accurately receiving data transmitted thereto over a single communication channel at a high rate of speed.

Detailed description

In the disclosed embodiment of the invention, a sending apparatus is adapted to generate and 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.

Since it is the number of impulses in a burst which indicates the symbol which the bursts represent, the impulses can be given sufficient amplitude at the sending station so that slight variations in the amplitude of the impulses which might make up the bursts will not be effective to cause errors in the reception of the data.

At the sending station, five symbols to be transmitted are set up on keys, and impulse-generating means is operable, under control of the keys, to generate five bursts of impulses, the impulses making up the bursts being generated at a rate of about 40 kilocycles. The bursts are transmitted over a single communication channel with a space or time interval of about 150 micro-seconds between successive bursts.

Inasmuch as this application is drawn particularly to the receiving apparatus, the details of the sending apparatus, or impulse-generating means, will not be given herein. Reference may be had to the parent application, Serial No. 477,096, for details of this apparatus if they are desired.

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

Receiving apparatus

The five bursts of negative potential impulses, which are generated in the sending apparatus and transmitted to the receiving apparatus, are impressed on signal input terminals **35** and **36** (Fig. 1) of the receiving apparatus.

The receiving apparatus, shown in Figs. 1 to 8 inclusive, accepts these bursts of impulses one after another and distributes them to different transforming and symbol-storing means.

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 acordingly to maintain the proper relation between the various parts of the circuit. Throughout the drawings, the cathode heater elements are shown conventionally.

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 **35** and **36** (Fig. 1) control the operation of a phase-changing vacuum tube **37**, which converts them into bursts of positive impulses. The bursts of positive impulses from tube **37** 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 **38** (Fig. 7) 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. 1 and includes a pair of vacuum tubes **40** and **41** connected to operate as a trigger pair; a slow-recovery control tube **42** for controlling the trigger pair; and a phase-changing and impulse-sharpening tube **43** controlled by tube **40** of the trigger pair for impressing an impulse on a firing impulse conductor **44** (Fig. 8) for the routing control device after each burst of impulses has been received.

Tube **40** of the trigger pair is normally conducting, and tube **41** is normally non-conducting; however, the first impulse of a burst is effective to render tube **41** conducting and tube **40** non-conducting. The impulses of a burst are also impresesd on the control tube **42** and cause this tube to apply a bias on tube **40** 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 **40** becomes conducting and controls the phase-changing and impulse-sharpening tube **43** to reduce conduction therein and thereby to cause a positive impulse to be impressed on the firing impulse conductor **44** 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 **37** is a zero-biased tube and is normally conducting. Anode **45** has a normal positive potential of 18 volts, which is derived from a positive potential of 150 volts applied at terminal **46**, over conductor **47**, point **48**, resistor **49** of 250 ohms, point **50**, and resistor **51** of 5,000 ohms. Point **50** is connected to ground over a stabilizing capacitor of .25 microfarad. The screen grid **52** has a potential of 105 volts applied thereto from terminal **53**, over conductor **54**, point **55**, resistor **56** of 500 ohms, and point **57**. Point **57** in this circuit is connected to ground over a stabilizing capacitor of 4 microfarads. The cathode **58** of this tube is connected directly to ground, and the control grid **59** is connected to ground over point **60** and resistor **61** of 25,000 ohms.

Point **60** in the circuit for control grid **59** is electrostatically coupled to input terminal **35** over capacitor **62** of 10 micro-microfarads, and, as the negative signal impulses from the sending station are impressed on the terminal, they will cause the potential of the control grid **59** to become negative and reduce conduction in tube **37**.

Since tube **37** is normally conducting, its anode **45** will have a normal positive potential of about 18 volts due to the potential drop across resistors **49** and **51**, but, whenever a negative signal impulse is impressed on the control grid and stops conduction in the tube, the potential of the anode **45** will rise and provide a positive impulse. As indicated earlier herein, the amplitude of the impulses which are transmitted is made large enuough 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 **37**. A potential-tapping member **63** cooperates with resistor **51** and enables this potential rise, which occurs each time conduction ceases in tube **37**, to be utilized as a positive impulse for controlling the control impulse generating means, and also to be impressed on the common impulse conductor **38** (Fig. 7) 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 **63** to the common impulse conductor **38** extends over point **64** and terminal **65** (Fig. 1), which is connected to terminal **66** (Fig. 7), to which the common impulse conductor **38** is connected. The manner in which the positive impulses on conductor **38** are relayed to and are effective to operate the transforming and symbol-storing means will be explained hereinafter.

Conductor **67** (Fig. 1) extends from point **64** and enables the positive impulses to control the control impulse generating means.

The tubes **40** and **41** are connected to form a trigger pair in which tube **40** is normally conducting and tube **41** is normally non-conducting. Anode **70** of tube **41** has a positive potential of 150 volts applied thereto from point **71** on conductor **47**, over resistor **72** of 250 ohms, point **73**, resistor **74** of 5,000 ohms, and conductor **75**; and, since tube **41** is normally non-conducting, anode 70 will be at a positive potential of 150 volts. Point 73 in this circuit is connected to ground over a stabilizing capacitor of .25 microfarad. Screen grid 76 of tube 41 has a positive potential of 105 volts applied thereto from point 55 on conductor 54, over resistor 77 of 500 ohms, point 78, and conductor 79. Point 78 in this circuit is connected to ground over a stabilizing capacitor of 4 microfarads. The suppressor grid 80 and cathode 81 of tube 41 are connected directly to ground.

The control grid 85 of tube 41 is given a normal negative bias by being connected to a circuit which starts at terminal 86, upon which a negative potential of 150 volts is impressed, and continues to ground over conductor 87, point 88, resistor 89 of 30,000 ohms, and resistor 90 of 10,000 ohms, the connection of the control grid 85 to this circuit being over point 91, resistor 92 of 25,000 ohms, point 93, and potential-tapping member 94, which cooperates with resistor 90 and is adjustable to enable the proper negative bias to be obtained on the control grid 85. Point 93 in this circuit is connected to ground over a stabilizing capacitor of 10 microfarads. A further connection from point 91 in the control grid circuit extends over point 95 and capacitor 96 of 10 micro-microfarads to conductor 67, upon which is impressed a positive impulse from tube 37 each time a signal impulse is received over input terminal 35, and enables these positive impulses to be impressed on control grid 85. The trigger connection between control grid 85 of tube 41 and the anode 97 of tube 40 extends from points 91 and 95, over resistor 98 of 50,000 ohms in parallel with capacitor 99 of 50 micro-microfarads to point 100 in the anode potential supply circuit for tube 40.

Tube 40 is normally conducting. Anode 97 has a normal positive potential of 20 volts derived from a positive potential of 150 volts applied from point 71 on conductor 47, over resistor 72 and point 73, and over resistor 101 of 5,000 ohms to points 102 and 100. The screen grid 103 of tube 40 has a positive potential of 105 volts applied thereto by being connected at point 104 to conductor 79, which also supplies this potential to the screen grid 76 of tube 41.

Cathode 105 and suppressor grid 106 of tube 40 are connected directly to ground.

The control grid 107 of tube 40 is connected at point 108 to a circuit which starts at point 109 on the negative potential supply conductor 87 and continues over resistor 110 of 150,000 ohms, points 111 and 108, resistor 112 of 100,000 ohms, and variable resistor 113 of 50,000 ohms to point 114, and then to point 115, to which the anode 120 of control tube 42 is connected. The anode 120 is normally at a positive potential of about 90 volts and causes the potential of the control grid 107 to be such that tube 40 will be conducting; however, when tube 42 has been rendered conducting and the potential of its anode 120 has dropped, this drop will cause the potential of the control grid 107 to become sufficiently negative to prevent conduction from occurring in tube 40. The trigger connection between control grid 107 and the anode 70 of tube 41 extends from point 111 in the control grid circuit, over resistor 121 of 50,000 ohms and capacitor 122 of 50 micro-microfarads in parallel to points 123 and 124 on the conductor 75, to which anode 70 of tube 41 is connected.

Control tube 42 is normally non-conducting but is rendered conducting each time a positive impulse occurs on conductor 67.

In addition to the circuit traced earlier herein which extends to control grid 107 of tube 40, the anode 120 of control tube 42 is also connected to ground over points 114 and 115 and capacitor 125 of 900 micro-microfarads, and is connected to conductor 47 over point 115, resistor 126 of 75,000 ohms, point 127, resistor 128 of 500 ohms, and point 71. Point 127 is connected to ground over a stabilizing capacitor of 1 microfarad. The screen grid 130 of the control tube 42 is connected to point 127 in the circuit between the anode 120 and the conductor 47. The cathode 131 of the control tube 42 is connected directly to ground.

The control grid 132 for the control tube 42 is given a negative bias by being connected to a circuit which starts from point 88 on the negative potential supply conductor 87 and continues to ground over resistor 133 of 50,000 ohms and resistor 134 of 10,000 ohms, the connection being over point 135, resistor 136 of 100,000 ohms, point 137, and an adjustable potential-tapping member 138, which cooperates with resistor 134 to enable the desired negative bias to be applied to the control grid. Point 137 in this circuit is connected to ground over a stabilizing capacitor of 10 microfarads, and point 135 is electrostatically coupled over capacitor 139 of 50 micro-microfarads and point 140 to conductor 67, 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 40 and 41 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 35 of the receiving apparatus, it will cause the phase-changing tube 37 to be effective to impress a positive impulse on conductor 67. The first impulse of a burst on conductor 67 will be effective through capacitor 96 to reduce the bias on the control grid 85 of tube 41 and will render this tube conducting. When tube 41 becomes conducting, the potential of its anode 70 will drop, and this drop is effective through the trigger connection to render tube 40 non-conducting.

The first impulse on conductor 67 will also be effective, through capacitor 139, to reduce the bias on the control grid 132 of control tube 42 and render this tube conducting. When the control tube 42 becomes conducting, the potential of its anode 120 will drop, and, since the control grid 107 of tube 40 is connected to the anode 120, this potential drop will cause the potential of the control grid 107 to become sufficiently negative to prevent conduction from occurring in tube 40. The values for capacitor 125 and resistor 126 in the circuit with anode 120 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 42, which was caused by the impulse, has ceased. The rise in anode potential is so regulated that the next impulse on conductor 67 is effective to render the control tube conducting again before the anode potential has recovered sufficiently to reduce the bias on control grid 107 to a point where tube 40 will become conducting. As the control tube 42 becomes conducting in response to the next impulse on conductor 67, the potential of the anode 120 will drop an amount equal to that which it had recovered after the previous conduction in tube 42 has ceased. Accordingly, the potential of the anode 120 will drop when the control tube 42 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 107 of tube 40 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 42 will not be rendered conducting, and the potential of its anode 120 can recover sufficiently to be effective to reduce the bias on control grid 107 of tube 40, and that tube can be rendered conducting.

The adjustable resistor 113, which is included in the circuit between the anode 120 and the control grid 107, enables the selection of the point at which the potential rise of the anode 120 will cause the control grid 107 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 40 remains non-conducting, it will be effective, through the trigger connection, to cause tube 41 to remain conducting between impulses; however, as tube 40 is rendered conducting during the interval between bursts, it will cause tube 41 to become non-conducting, and, as tube 41 becomes non-conducting, it will be effective through the trigger connection to cause a rapid rise in the rate of conduction in tube 40.

The potential of anode 97 of tube 40 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 150 of the phase-changing and impulse-sharpening tube 43, over point 102, capacitor 151 of 50 micro-micro-farads, and point 152.

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 43 is normally conducting but is rendered non-conducting each time tube 40 becomes conducting. The anode 153 of tube 43 has a positive potential of 150 volts applied thereto by a circuit starting from point 48 on conductor 47 and continuing over resistor 154 of 250 ohms, point 155, and resistor 156 of 5,000 ohms. Point 155 in this circuit is connected to ground over a stabilizing capacitor of .25 microfarad. Although anode 153 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 156. Screen grid 157 has a positive potential of 105 volts applied thereto over point 78 on conductor 79, which, as explained earlier herein, also supplies this potential to the screen grids of the tubes of the trigger pair. The suppressor grid 158 and cathode 159 of this tube are connected directly to ground, and its control grid 150 is connected to ground over point 152 and resistor 160 of 10,000 ohms.

When conduction is decreased in tube 43 as tube 40 becomes conducting, the potential of anode 153 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 44 (Fig. 8) of the routing control device by means of a potential-tapping member 161, which cooperates with resistor 156 and is also connected to terminal 162, which is connected to terminal 163 (Fig. 8), to which the firing impulse conductor 44 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. 2 to 6 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. 2, 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. 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. 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 tubes in the bank are connected for sequential firing, beginning with the presetting tube, and continuing with the symbol-storing tubes for the digits from "0" to "9" inclusive, in that order. The symbol-storing tubes are fired one after another in response to impulses relayed to a firing impulse conductor from the common impulse conductor 38 (Fig 7). 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 of the bank can respond accurately to the impulses impressed thereon at a rate of about 40 kilocycles and accordingly provide a fast and reliable means for transforming the bursts of impulses into a direct representation of the symbol corresponding to the number of impulses in a 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. 2) by means of parallel circuits, one for each tube, extending to ground from a negative potential conductor 170, to which a negative potential of 150 volts is applied at terminal 171. The circuit for the "8" tube is representative and extends from the supply conductor 170 at point 172, over resistor 173 of 150,000 ohms, point 174, resistor 175 of 100,000 ohms, points 176, 177, and 178, and to ground over resistor 179 of 15,000 ohms in parallel with resistor 180 of 2,500 ohms and capacitor 181 of .002 microfarad in series. Cathode 182 of the "8" tube is connected to this circuit at point 177 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 182 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 183 on the potential supply conductor 170, over resistor 184 of 150,000 ohms, resistor 185 of 100,000 ohms, points 186, 187, and 188, and to ground over resistor 189 of 15,000 ohms in parallel with a resistor 190 of 2,500 ohms in series with a capacitor 191 of .002 microfarad. Cathode 192 of the "9" tube is connected to this circuit at point 186.

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 195. The grid of the "9" tube, for instance, is connected over resistor 196 of 50,000 ohms, point 197, resistor 198 of 500,000 ohms, point 199, and conductor 200 to point 174 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 201 of 250 micro-microfarads connects point 199 in the grid circuit with point 176 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 205 on the conductor 170, over resistor 206 of 120,000 ohms, points 207 and 208, and resistor 209 of 90,000 ohms to ground, to which the control grid 210 is connected at point 208.

The grids of the tubes in the sequence from the "0" tube to the "9" tube are electrostatically coupled to the firing impulse conductor 195 by means of capacitors of 10 micro-microfarads, as capacitor 211, by which point 197 in the grid circuit of the "9" tube is connected to the firing impulse conductor 195. The firing impulse conductor 195 extends from the terminal 212, and

this terminal is connected to terminal 213 (Fig. 7) of the relay means which relays the impulses from the common impulse conductor 38 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 215, which is connected over resistor 216 of 2,000 ohms, point 217, and resistor 218 of 250 ohms to terminal 219, which has a positive potential of 75 volts applied thereto. Point 217 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 220. The circuit starts at terminal 221, upon which a positive potential of 150 volts is impressed, and continues over conductor 222, key 220, conductor 223, and resistor 224 of 120,000 ohms, to point 207 in the circuit for the control grid 210. When this circuit is closed by the key 220, 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 momentary depression of the presetting key 220 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 195 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 225, 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 226, 227, 228, and 229 (Figs. 3, 4, 5, and 6), 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 230, 231, 232, and 233 for the "II," "III," "IV," and "V" banks (Figs. 3, 4, 5, and 6) are connected to terminals 234, 235, 236, and 237 which terminals are connected to terminals 238, 239, 240, and 241, respectively (Fig. 7), 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 transmitted thereto from 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 38 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 38 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. 8) 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 banks of transforming and symbol-storing tubes, 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 38; 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. 8, in which the control tubes are given the reference numerals "I," "II," "III," "IV," and "V" to indicate with which of the bursts 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 245 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 246 for the "II" control tube. The one branch extends from a negative potential supply conductor 247, to which a negative potential of 150 volts is applied at terminal 248, and continues over point 249, resistor 250 of 300,000 ohms, point 251, and resistor 252 of 150,000 ohms to points 253, 254, and 255. The other branch extends from the potential supply conductor 247 at point 256 and continues over resistor 257 of 300,000 ohms, point 258, and resistor 259 of 200,000 ohms to the points 254 and 255. From the points 254 and 255, the two branches continue to ground over resistor 260 of 15,000 ohms in parallel with resistor 261 of 2,500 ohms and capacitor 262 of .002 microfarad in series. The cathode 245 is connected at point 254 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 251 in said one branch and continues over conductor 242, point 243, conductor 263, and terminal 264, which is connected to terminal 265 (Fig. 7) 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 245, due to conduction in the control tube, to be used to reduce the negative bias or "prime" the relay means.

A capacitor 266 of 50 micro-microfarads is connected between points 253 and 243 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 258 and continues over resistor 267 of 500,000 ohms, point 268, and resistor 269 of 50,000 ohms to grid 246 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 245 when the "I" tube is conducting.

Grid 246 of the "II" tube is connected over point 268 and capacitor 270 of 10 micro-microfarads to the impulse conductor 44, which is connected to terminal 163, upon which is impressed a positive impulse by the control impulse generating means after each burst of impulses has 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 271 on conductor 247 and over resistor 272 of 150,000 ohms, point 273, and resistor 274 of 100,000 ohms to ground supplies grid 275 with a negative biasing potential of about 60 volts over point 273 and resistor 276 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 277 (Fig. 8) can be momentarily depressed to close a circuit starting from terminal 278, upon which a positive potential of 150 volts is impressed, and continuing over the key 277, resistor 279 of 150,000 ohms to point 273 in the circuit of grid 275. The application of this positive potential to the grid 275 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 277 may be closed by a presetting relay along with the presetting circuits of the transforming and symbol-storing banks, as explained earlier herein.

Potential is applied to the anode 280 of the "I" tube by means of a circuit starting at terminal 281, upon which is impressed a positive potential of 75 volts, and extending over resistor 282 of 250 ohms, point 283, resistor 284 of 2,000 ohms, and conductor 285, to which anode 280 is connected. The anodes of the other tubes are also connected to conductor 285, and, when none of the tubes is conducting, the potential of the anodes will be 75 bolts, but, when any tube is conducting, this potential is reduced to about 65 volts due to the resistors 282 and 284. Point 283 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 description, 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. 7 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. 7 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 290 and 291, which constitute the means for relaying impulses from the common impulse conductor 38 to the first bank of transforming and symbol-storing tubes, are normally inoperative to relay the positive impulses from the common impulse conductor 38, because the control grid 292 of tube 290 is normally given a negative bias which the positive impulses cannot overcome. The tube 290 is "primed" by having the negative bias of its grid 292 reduced, and in this condition the tube can respond to the positive potential impulses on the common impulse conductor 38 and can cause the impulses to be relayed to the firing impulse conductor 195 (Fig. 2) for the first bank of transforming and symbol-storing tubes.

The cathode 293 of tube 290 is connected directly to ground. The anode 294 of this tube is given a positive potential of 150 volts over a circuit starting at terminal 295, upon which is impressed a positive potential of 150 volts, and continuing over potential supply conductor 296, point 297, resistor 298 of 500 ohms, points 299 and 300, resistor 301 of 5,000 ohms, and point 302 to the anode 294. The screen grid 303 is given a normal positive potential of 150 volts by being connected to point 300 in the above anode circuit. Suppressor grid 304 is directly connected to ground.

The control grid 292 is connected over point 305 and resistor 306 of 10,000 ohms to terminal 265, 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 292 is also connected electrostatically to the common impulse conductor 38 from point 305 over a capacitor 307 of 100 micro-microfarads. The potential on the grid 292 is normally sufficiently negative that the tube 290 is not responsive to the positive potential impulses on the impulse conductor 38, but, when the "I" control tube of the routing control device is conducting, the potential rise of its cathode 245 will reduce the negative potential of grid 292, or "prime" the tube 290 so that it will be capable of responding to the impulses on conductor 38 and become conducting each time an impulse occurs on that conductor.

Whenever tube 290 becomes conducting, the potential of its anode 294 will drop due to the resistors 298 and 301 in its anode potential supply circuit, and, through an electrostatic connection from point 302 in this circuit over capacitor 308 of 100 micro-microfarads and point 309, this drop is applied as a negative potential impulse on control grid 310 of the phase-changing and amplifying tube 291.

Tube 291 is a zero-biased tube and is normally conducting. This tube has its cathode 311 directly connected to ground; its screen grid 312 connected over point 313 and resistor 314 of 500 ohms, point 315, and conductor 316 to terminal 317, to which is applied a positive potential of 105 volts; and its control grid 310 connected to ground from point 309 over resistor 318 of 10,000 ohms, and also electrostatically connected to the anode 294 of tube 290, as explained above.

The anode 320 of the phase-changing and amplifying tube 291 is connected over resistor 321 of 5,000 ohms, point 322, and resistor 323 of 250 ohms to point 324 on the potential supply conductor 296, which is connected to terminal 295, to which is applied a positive potential of 150 volts. Point 322 in this circuit is connected to ground over a stabilizing capacitor of .25 microfarad. As this tube is normally conducting, anode 320 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 325 cooperates with resistor 321 to enable this rise to be utilized as a positive potential impulse which is impressed on the firing impulse conductor 195 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 325 to the firing impulse conductor extends from the potential-tapping member 325 over conductor 326 to terminal 213, which, as explained above, is connected to terminal 212 (Fig. 2), to which the firing impulse conductor 195 is connected.

The other relay means will, when effective, relay impulses from the common impulse conductor 38 to the firing impulse conductors of their respective banks.

Terminals 327, 328, 329, and 330 (Fig. 8), which are connected to terminals 331, 332, 333, and 334, respectively (Fig. 7), 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 238 (Fig. 7) is connected to terminal 234 (Fig. 3), to which the firing impulse conductor 230 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 38.

Similarly, terminals 239, 240, and 241 (Fig. 7) are connected to terminals 235, 236, and 237 of Figs. 4, 5, and 6, respectively, to enable the third, fourth, and fifth bursts of impulses to be relayed to the firing conductors 231, 232, and 233 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

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 banks of transforming and symbol-storing tubes 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 generated in the sending apparatus at a rate of about 40 kilocycles and transmitted to the receiving apparatus are impressed on the receiving apparatus. These impulses are changed in the receiving apparatus 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 means 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, in which 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 super-sonic 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.

While the form of the invention shown and described herein 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 disclosed herein, 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 receiving apparatus for a communication system in which different numbers of signal impulses are assigned to represent different symbols which may be transmitted and in which a symbol is transmitted as a burst of impulses containing a number of equal amplitude impulses greater than is necessary to properly operate the receiving apparatus so that variations in the amplitude of the impulses during transmission will not affect the operation of the receiving apparatus, the combination of a plurality of means differentially operable in response to the different numbers of impulses representing the symbols, to transform the signals into direct representations of these symbols; input means which responds in the same manner to each signal impulse and upon which the bursts of signal impulses representing the various symbols being received are impressed one after another with a space or time interval between bursts; an impulse conductor common to said plurality of differentially operable means and upon which an impulse is impressed by the input means when each signal impulse is impressed on the input means; a normally inoperable relay device related to each of said plurality of differentially operable means, said relays being effective one at a time for selectively relaying impulses thereto from the impulse conductor; control means upon which an impulse is impressed by the input means each time a signal impulse is impressed on the input means and which is operable to generate a control impulse during the space between bursts; said control means including a pair of vacuum tubes connected to form a trigger pair in which one of the tubes is normally conducting and the other of the tubes is normally non-conducting, including means controlled from the input means for impressing the signal impulses on said other tube of the trigger pair to cause that tube to become conducting, and through the trigger connection, to cause said one tube of the pair to become non-conducting, including quick-acting, slow-recovery means controlled by signal impulses from the input means to apply a bias to said one tube of the trigger pair to prevent it from again becoming conducting as long as impulses of the burst are impressed on the input means, and including means controlled by the trigger-pair to generate a control impulse for each complete excursion of the trigger pair and means operated by the control impulse generated by the control means to cause the various relay means to be operable one at a time in succession and be effective to relay the impulses of the successive bursts from the common impulse conductor to different ones of said plurality of differentially operable means to cause direct representations of the symbols represented by the bursts of signal impulses to be set up.

2. In a receiving apparatus for a communication system in which different numbers of impulses are assigned to represent different symbols which may be transmitted and in which the impulses for each symbol are substantially identical, the combination of a plurality of banks of gaseous electron tubes; means connecting the tubes in each bank for step-by-step operation in sequence in response to the impulses, the different numbers of impulses forming bursts and causing different numbers of tubes to be operated to provide direct representations of the symbols; input means upon which bursts of impulses are impressed in succession, each burst containing a number of substantially identical impulses according to the symbol which it represents; a common impulse conductor having an impulse impressed thereon by the input means for each impulse in each burst that is received; a thermionic valve related to each of said plurality of banks for selectively relaying impulses from the common conductor to its related bank of tubes to cause a number of tubes therein to be operated according to one of the bursts of signals; means normally giving the thermionic valves a sufficient bias so that they will not respond to the impulses; control impulse generating means controlled by the input means to generate a control impulse for each burst of impulses impressed on the input means; electronic devices; circuits interconnecting the electronic devices in a chain to be operable one at a time in sequence by the control impulses, said interconnecting circuits enabling conduction in a device of the chain to prime the next device in the chain for operation in response to the next control impulse impressed on the chain; and circuits connecting the electronic devices to the thermionic valves for reducing the bias on the thermionic valves one after another as the devices operate in sequence to enable the valves to respond to the impulses and route the successive bursts into different banks of tubes.

3. In an impulse generating means, the combination of a pair of vacuum tubes connected to form a trigger pair in which one of the tubes is normally conducting and the other of the tubes is normally non-conducting; input means upon which impulses of a group of impulses are impressed; means controlled from the input means for impressing the impulses on said other tube of the trigger pair to cause that tube to become conducting, and, through the trigger connection, to cause said one tube to become non-conducting; quick-acting, slow-recovery means controlled by the impulses from the input means to apply a bias to said one tube to prevent it from again becoming conducting as long as impulses of the group are impressed on the input means; and means controlled by the trigger pair to generate an impulse for each complete excursion of the trigger pair.

4. In a device responsive to a group of impulses, the combination of a pair of vacuum tubes connected to form a trigger pair in which one tube is normally conducting and the other tube is normally non-conducting; means to impress the impulses of a group on said non-conducting tube to cause that tube to become conducting and, through the trigger connection, cause said one tube to become non-conducting; a control tube; means to impress said impulses on said control tube; and means controlled by said control tube for applying a bias on said one tube of the trigger pair to prevent conduction therein as long as impulses in a group are impresed on the control tube; said means controlled by the control tube removing the bias and allowing the normally conducting tube of the trigger pair to return to its normal conducting state after all the impulses

of the group have been impressed on the control tube; and said tubes of the trigger pair generating a signal for each excursion of the pair from its normal condition.

5. In a device responsive to spaced groups of impulses, the combination of a pair of vacuum tubes connected to form a trigger pair in which one tube is normally conducting and the other tube is normally non-conducting; means to impress the impulses of the groups on said non-conducting tube to cause that tube to become conducting and, through the trigger connection, cause said one tube to become non-conducting; a control tube; means to impress said impulses on said control tube to cause said tube to be operated for each impulse; means controlled by said control tube as it is operated by the impulses, for quickly applying a bias on said one tube and maintaining the bias between successive impulses of a group to prevent conduction in said one tube as long as impulses in a group are impressed on the control tube; said means controlled by the control tube removing the bias and allowing the normally conducting tube of the trigger pair to return to its normal conducting state during the time interval or space between groups of impulses; and means enabling said tubes of the trigger pair to generate a signal in response to each group of impulses.

6. In a device responsive to spaced groups of impulses, the combination of a pair of vacuum tubes connected to form a trigger pair in which one tube is normally conducting and the other tube is normally non-conducting; means to impress the impulses of the groups on said non-conducting tube to cause that tube to become conducting and, through the trigger connection, cause said one tube to become non-conducting; a control tube; means to impress said impulses on said control tube; and quick-acting, slow-recovery means controlled by said control tube for applying a bias on said one tube and operable, due to the slow-recovery characteristic, to maintain the bias and prevent conduction in said tube as long as impulses in a burst are impressed on the control tube; said slow-recovery means recovering sufficiently to remove the bias and allow the normally conducting tube of the trigger pair to return to its normal conducting state during the time interval or space between bursts; and said tubes of the trigger pair generating a signal for each excursion of the pair from its normal condition.

7. In a device responsive to a group of impulses, the combination of a pair of vacuum tubes having elements therein connected to enable the tubes to operate as a trigger pair in which one tube is normally conducting and the other tube is normally non-conducting; means to impress the impulses of a group on one of the elements of the non-conducting tube to cause that tube to become conducting and, through the trigger conection, cause said one tube to become non-conducting; a control tube having elements therein; means to impress the impulses of a group on one of the elements of the control tube to cause that tube to respond to each impulse of the group; quick-acting, slow-recovery means, including a resistor and capacitor connected to another element of said control tube and rendered operable thereby, for applying and maintaining a bias on one of the elements of said one tube to prevent its return to conducting condition as long as the impulses of a group are impressed on the control tube; and a resistor connected to one of the elements of one of the trigger tubes to enable an impulse to be derived therefrom for each complete excursion of operation of the trigger pair.

8. In a device responsive to spaced groups of impulses, which impulses of the groups occur at substantially uniform predetermined intervals, the combination of a first vacuum tube having at least a control grid and an electrode; means to impress the impulses on the control grid to cause the tube to become conducting in response to each of the impulses; potential supplying means including a high resistance and a large capacitance connected to the electrode to control potential variations of the electrode as the tube responds to said impulses, said capacitance being connected across the tube and the value of said resistance and capacitance being such that the potential of the electrode will drop sharply from a normal value to a predetermined value as the tube becomes conducting in response to the first impulse of a group but will return slowly while the tube is non-conducting between impulses and will not reach said normal value before the tube responds to the next impulse of the group and causes the potential of the electrode to drop again to said predetermined value, thereby preventing the potential of the electrode from returning to its normal value as long as impulses are impressed on the tube at said predetermined intervals; a normally conducting second vacuum tube having a control grid to control conduction therein; additional means upon which the impulses are impressed and which is operable in response to the first impulse of a group to apply a bias to the control grid of said second tube to render the second tube non-conducting; and a circuit connecting the electrode of the first tube to the control grid of the second tube to enable variations in the potential of the electrode of the first tube in response to the impulses to prevent conduction in the second vacuum tube as long as impulses are impressed on said first tube at said predetermined intervals.

9. In a device responsive to spaced groups of impulses, which impulses of the groups occur at substantially uniform predetermined intervals, the combination of a first vacuum tube having at least a control grid and an electrode; means to impress the impulses on the control grid to cause the tube to become conducting in response to each of the impulses; potential supplying means including a high resistance and a large capacitance connected to the electrode to control potential variations of the electrode as the tube responds to said impulses, said capacitance being connected across the tube and the value of said resistance and capacitance being such that the potential of the electrode will drop sharply from a normal value to a predetermined value as the tube becomes conducting in response to the first impulse of a group but will return slowly while the tube is non-conducting during the interval between impulses and will not reach said normal value before the tube responds to the next impulse of the group and causes the potential of the electrode to drop again to said predetermined value, thereby preventing the potential of the electrode from returning to its normal value as long as impulses are impressed on the tube at said predetermined intervals; a negative potential source; a potential dividing resistance network connecting the electrode of said first tube to the negative potential source, the potential in said network varying as the potential of said electrode varies in response to impulses applied to said first tube; a

second tube having a control electrode; means connecting the control electrode to said potential dividing network at a point therein which supplies the control electrode with a potential of a value which enables the second tube normally to have one state of conduction but which value will be changed as the first tube conducts in response to impulses and will cause the second tube to change its state of conduction and maintain the tube in the changed state as long as impulses are impressed on the first tube at said predetermined intervals, said potential dividing network including an adjustable resistor between the electrode of said first tube and the point where the control electrode of the second tube is connected to the network, for controlling the amount of recovery which might occur between impulses without affecting the state of conduction in the second tube and thereby determining the maximum permissible interval which might occur between successive impulses without changing the state of conduction in the second tube.

10. In a device of the class described which is responsive to groups of impulses which occur at a predetermined frequency, the combination of a first vacuum tube having at least three electrodes; means for applying said impulses to one of the electrodes of the tube to cause the tube to become conducting in response to each of said impulses; means connecting a second of said electrodes to a source of potential over a high resistance and to ground over a large capacitance; means connecting a third electrode directly to ground, said capacitance being short circuited by the tube and discharged therethrough whenever the tube becomes conducting, thereby causing the potential of the second electrode to drop sharply from a normal value each time the tube responds to an impulse, said capacitance being recharged through said high resistance slowly enough while the tube is non-conducting after each impulse that the potential of the second electrode will only partially return to normal value as long as impulses are applied to the tube at said predetermined frequency; a second vacuum tube having a plurality of electrodes; additional means upon which said impulses are impressed and operable in response to the first impulse of a burst to change the state of conduction in said second tube; and means connecting the second electrode of the first tube to one of the electrodes of the second tube to enable the first tube to maintain the second tube in its changed state while the other impulses of a group are received.

11. In a device of the class described which is responsive to impulses which occur at predetermined intervals, the combination of a normally non-conducting vacuum tube having at least an anode, a cathode, and a control grid; means for applying said impulses to the control grid to cause the tube to become conducting in response to each of said impulses; means connecting the anode to a source of positive potential over a high resistance and to ground over a large capacitance; means connecting the cathode directly to ground; said capacitance being short circuited by the tube and discharged therethrough whenever the tube becomes conducting, thereby causing the potential of the anode to drop sharply from a normal value each time the tube responds to an impulse, said capacitance being recharged through said high resistance slowly enough while the tube is non-conducting during the interval between impulses that the potential of the anode will not completely return to normal value as long as impulses are applied to the tube at said predetermined intervals; a negative potential source; a potential dividing resistance network connecting the anode of the normally non-conducting tube to the negative potential source, the potential in said network varying as the potential of the anode of said normally non-conducting tube varies; a second vacuum tube having a control grid; means connecting the control grid of the second tube to said potential dividing network at a point therein which supplies the grid of the second tube with a potential which allows the second tube to normally conduct but which enables the drop in potential of the anode to apply a negative bias to the control grid of the other tube to cause conduction therein to be stopped as long as impulses occur at said predetermined intervals, said potential dividing network including an adjustable resistor between said anode and the point to which the grid of the second tube is connected for controlling the amount of rise which might occur between impulses without allowing conduction to occur in said other tube, thereby controlling the maximum interval which might occur between impulses without allowing conduction to occur in said other tube.

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