COMMUNICATION SYSTEM

Filed Sept. 16, 1942 14 Sheets-Sheet 1

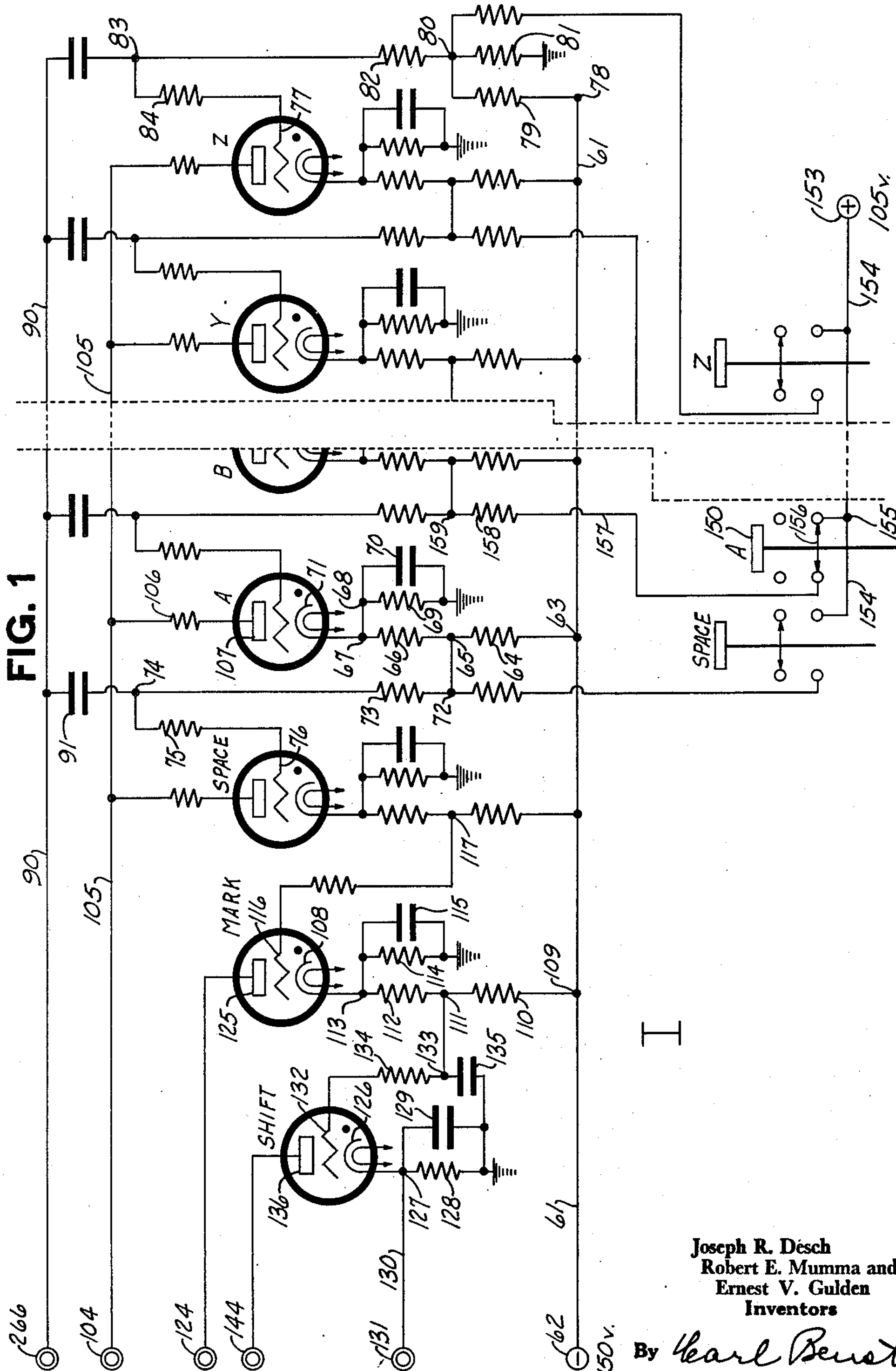


FIG. 1

Joseph R. Desch
Robert E. Mumma and
Ernest V. Gulden
Inventors

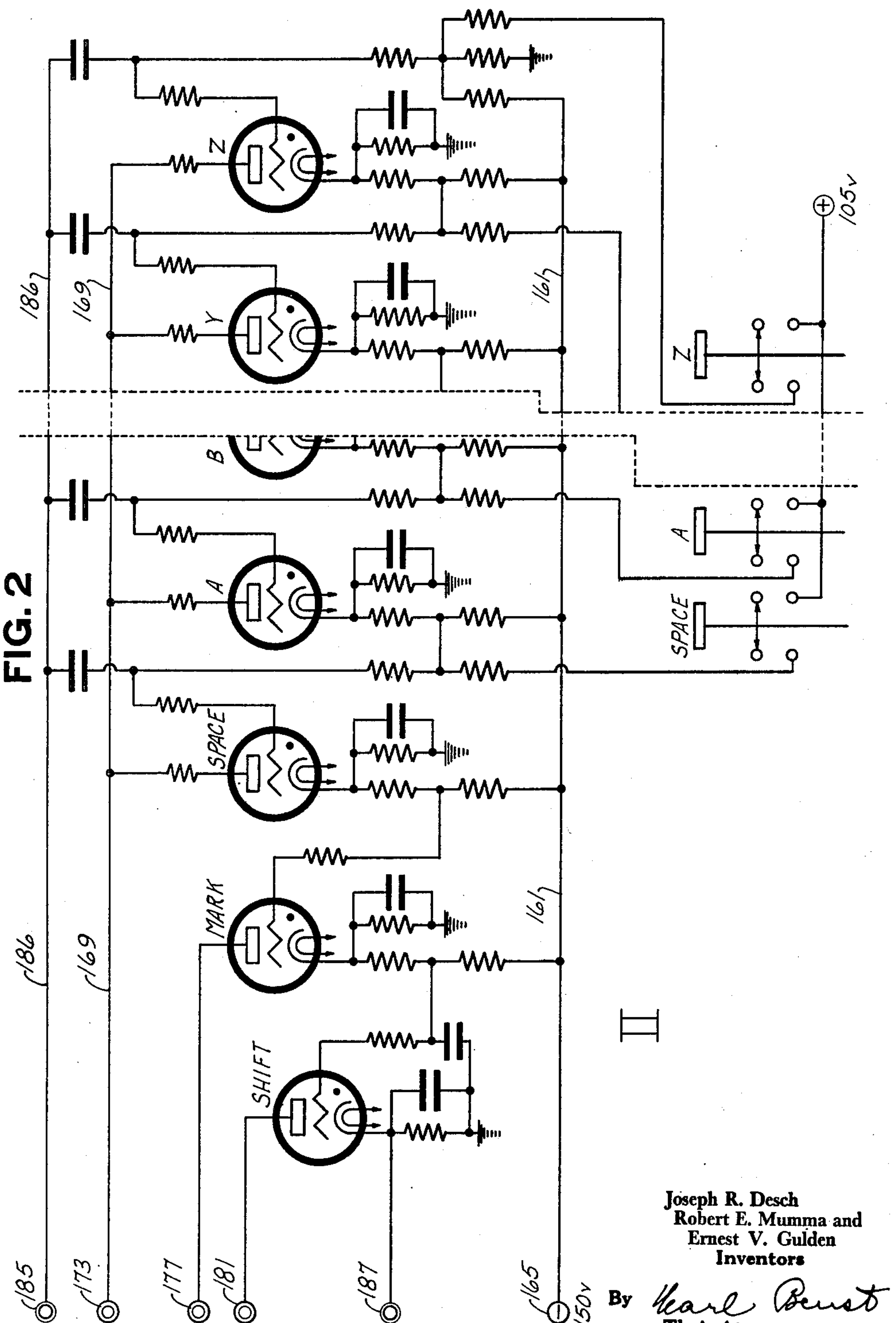
By Carl Beust
Their Attorney

Aug. 12, 1947. J. R. DESCH ET AL 2,425,307

COMMUNICATION SYSTEM

Filed Sept. 16, 1942 14 Sheets-Sheet 2

FIG. 2



Joseph R. Desch
Robert E. Mumma and
Ernest V. Gulden
Inventors

By Karl Benst
Their Attorney

COMMUNICATION SYSTEM

Filed Sept. 16, 1942 14 Sheets-Sheet 3

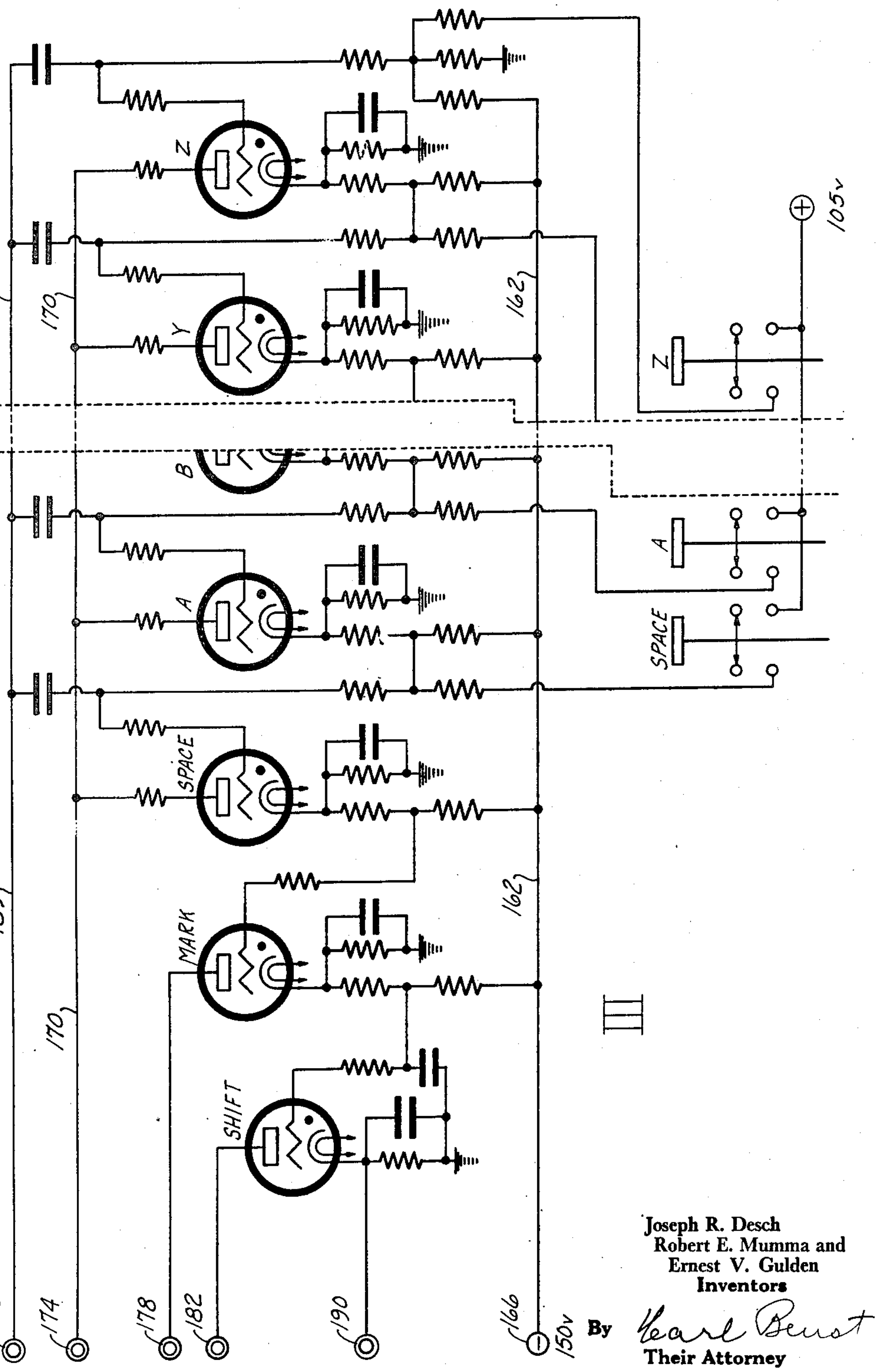


FIG. 3

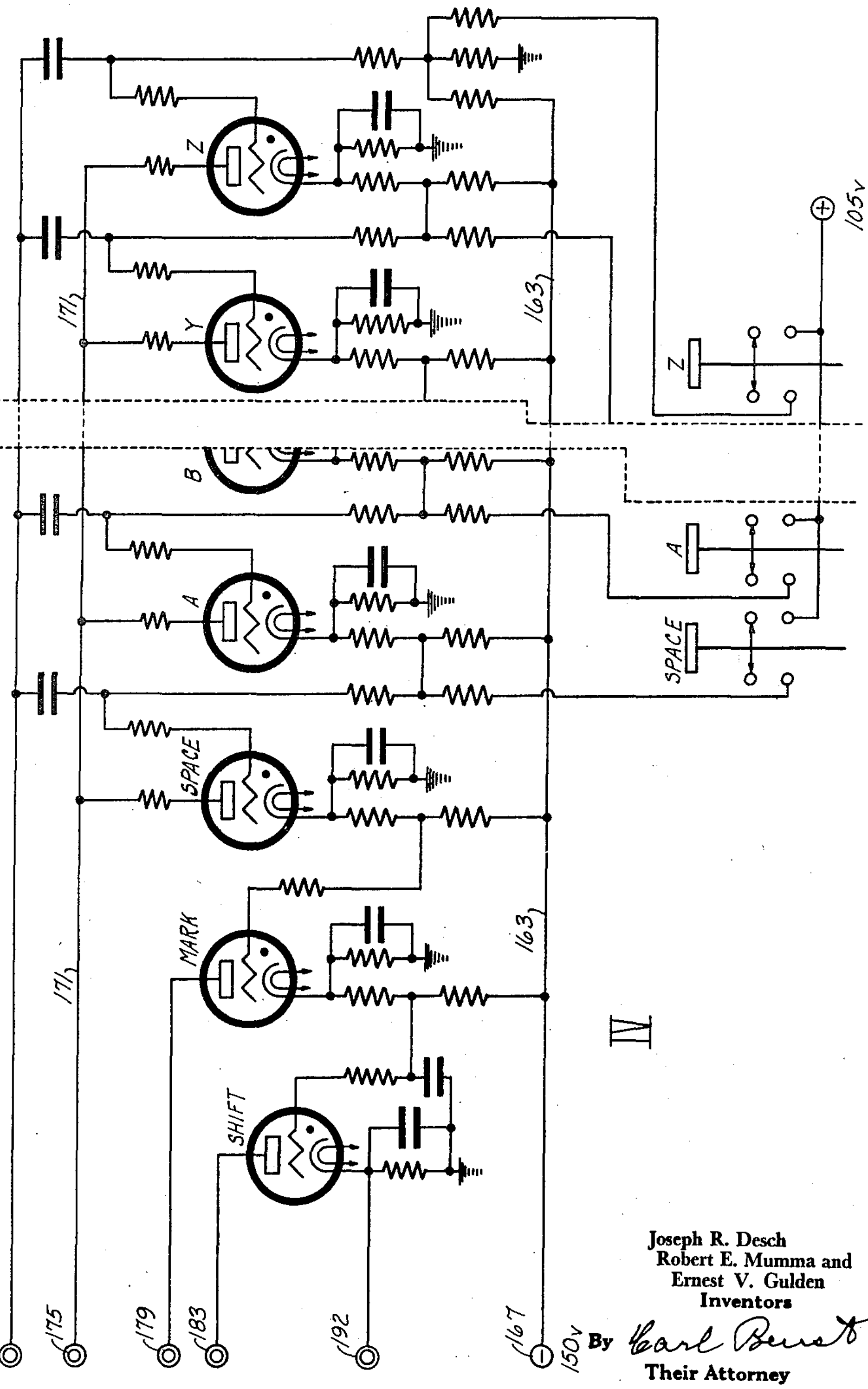
Joseph R. Desch
Robert E. Mumma and
Ernest V. Gulden
Inventors
By Earl Benst [signature]
Their Attorney

Aug. 12, 1947. J. R. DESCH ET AL 2,425,307

COMMUNICATION SYSTEM

Filed Sept. 16, 1942 14 Sheets-Sheet 4

FIG. 4



Joseph R. Desch
Robert E. Mumma and
Ernest V. Gulden
Inventors

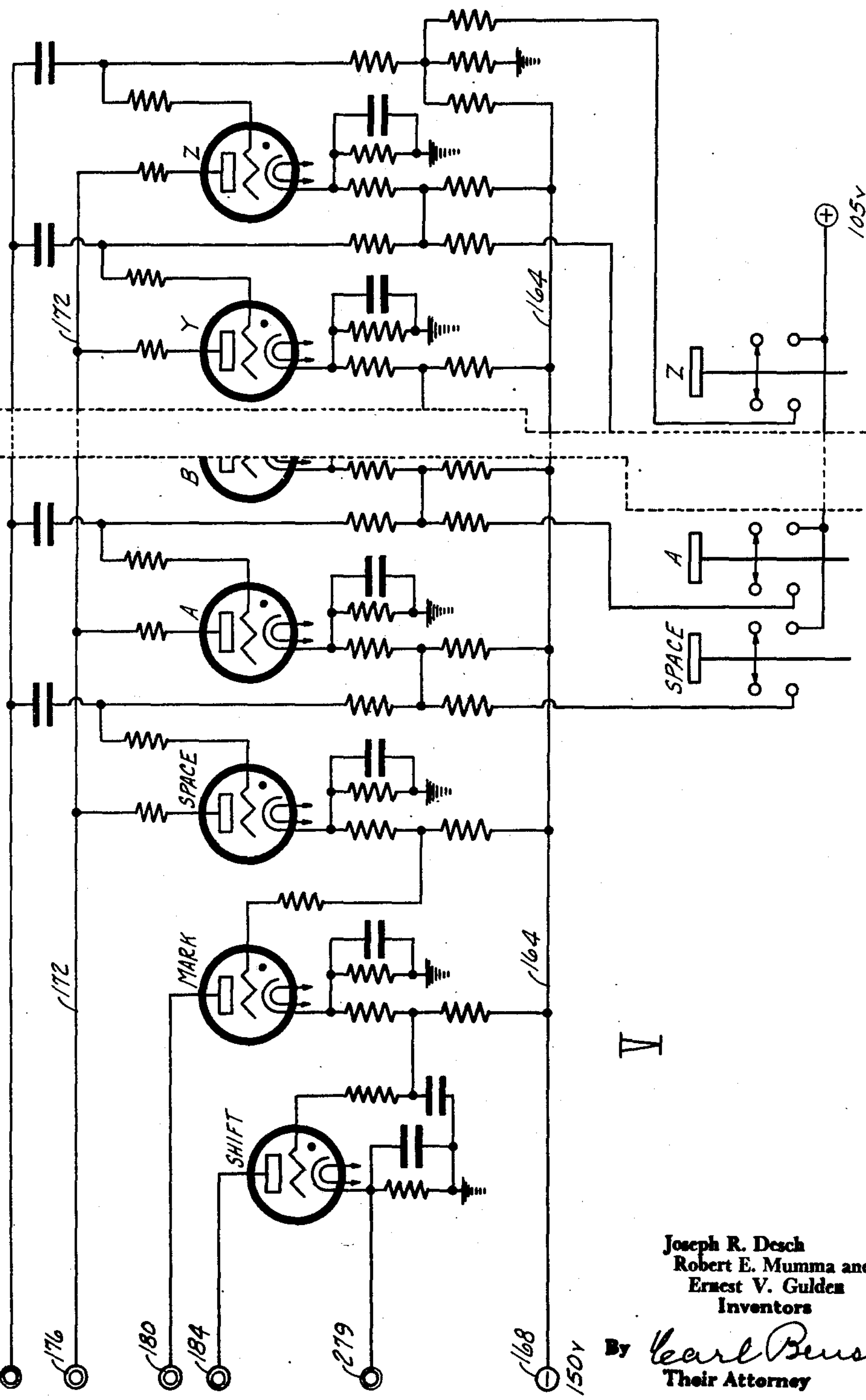
By Carl Beust

Their Attorney

COMMUNICATION SYSTEM

Filed Sept. 16, 1942 14 Sheets-Sheet 5

FIG. 5



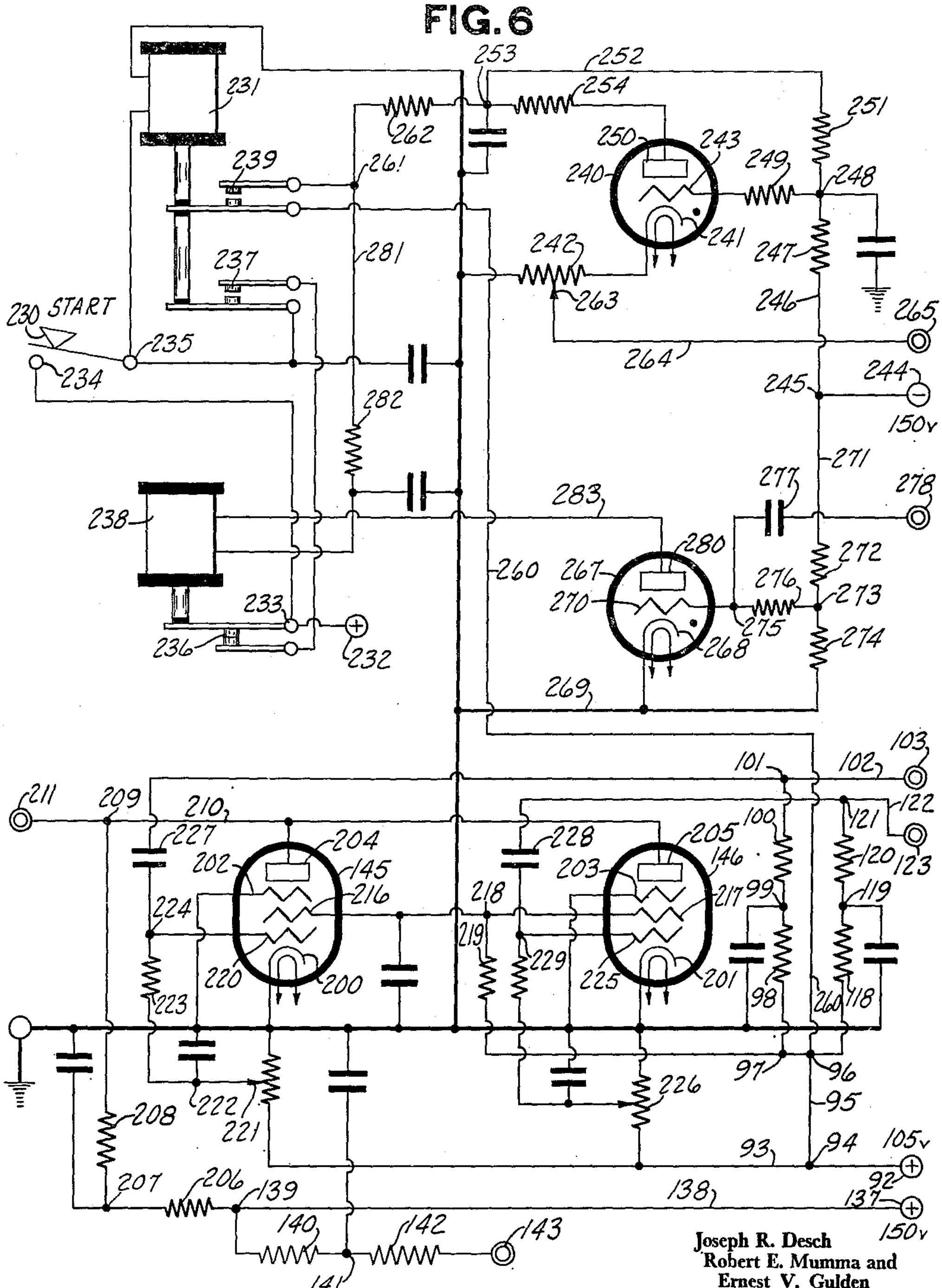
Joseph R. Desch
Robert E. Mumma and
Ernest V. Gulden
Inventors
By Carl Beust
Their Attorney

Aug. 12, 1947. J. R. DESCH ET AL 2,425,307

COMMUNICATION SYSTEM

Filed Sept. 16, 1942 14 Sheets-Sheet 6

FIG. 6



Joseph R. Desch
Robert E. Mumma and
Ernest V. Gulden
Inventors

By Carl Beust
Their Attorney

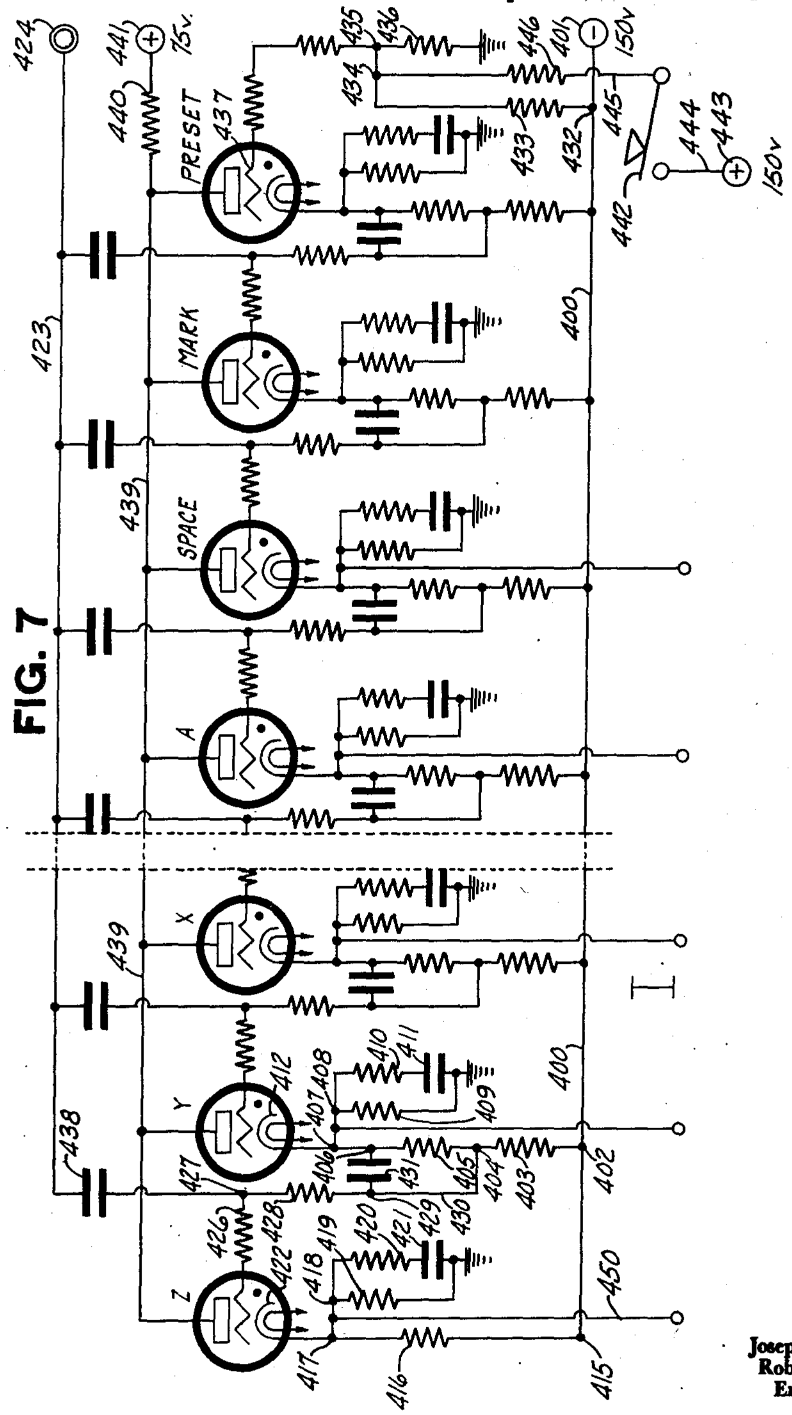


FIG. 7

Joseph R. Desch
Robert E. Mumma and
Ernest V. Gulden
Inventors

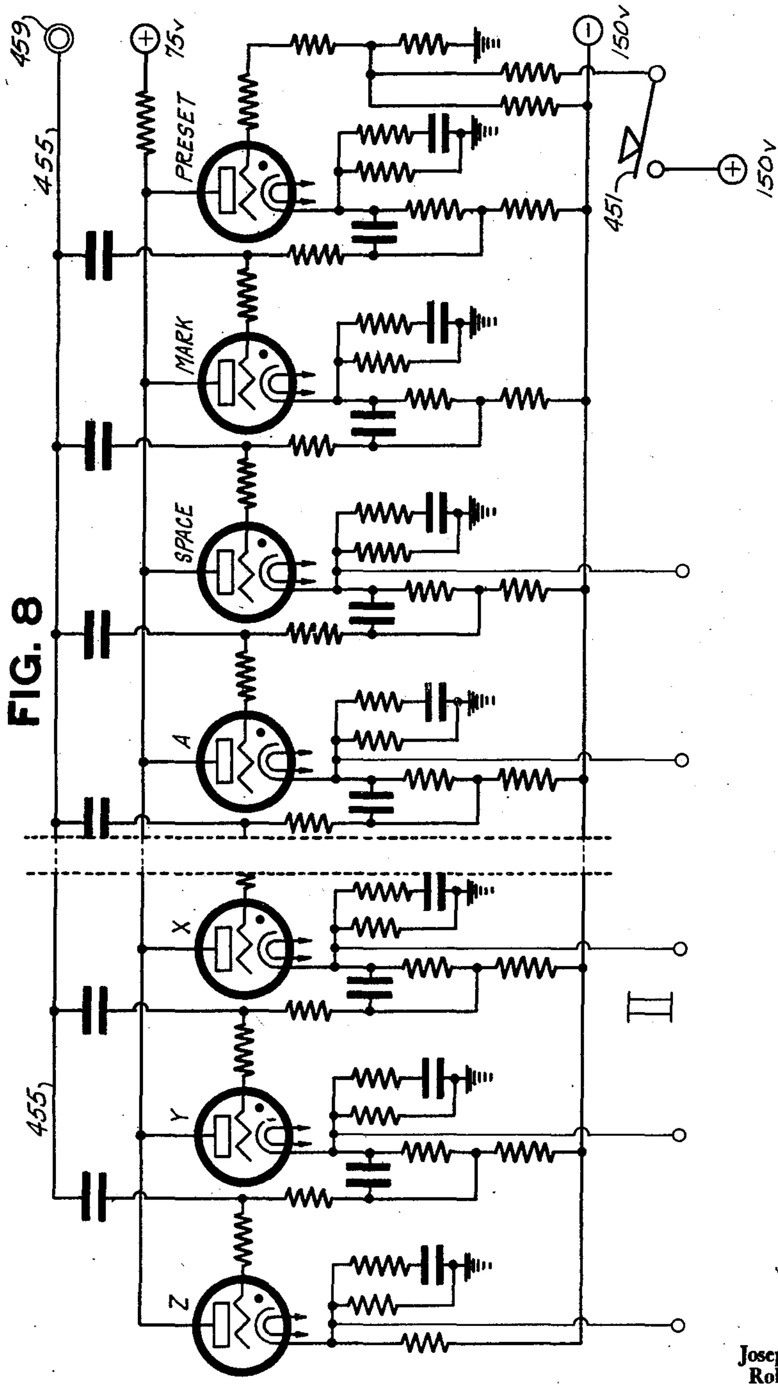
By Carl Beust
Their Attorney

Aug. 12, 1947. J. R. DESCH ET AL 2,425,307

COMMUNICATION SYSTEM

Filed Sept. 16, 1942 14 Sheets-Sheet 8

FIG. 8



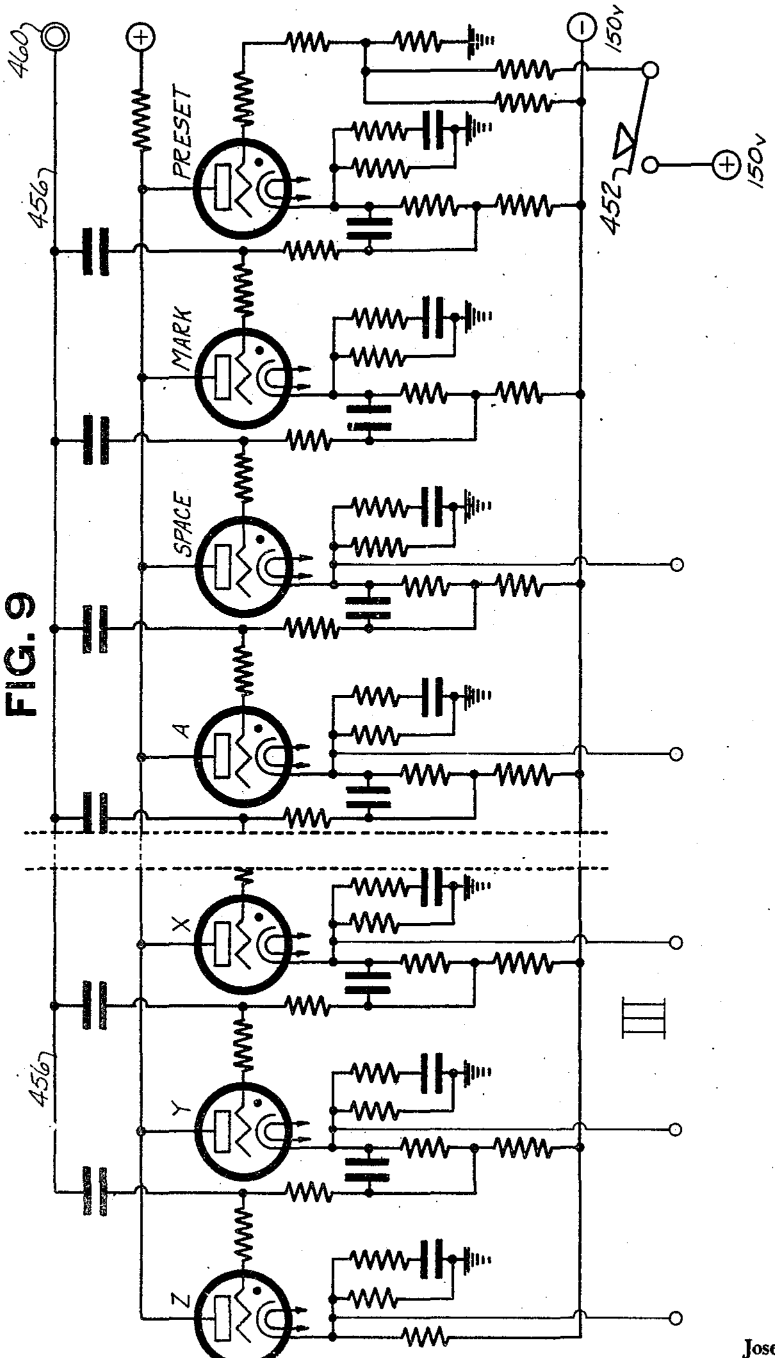
Joseph R. Desch
Robert E. Mumma and
Ernest V. Gulden
Inventors

By Earl Beust
Their Attorney

COMMUNICATION SYSTEM

Filed Sept. 16, 1942 14 Sheets-Sheet 9

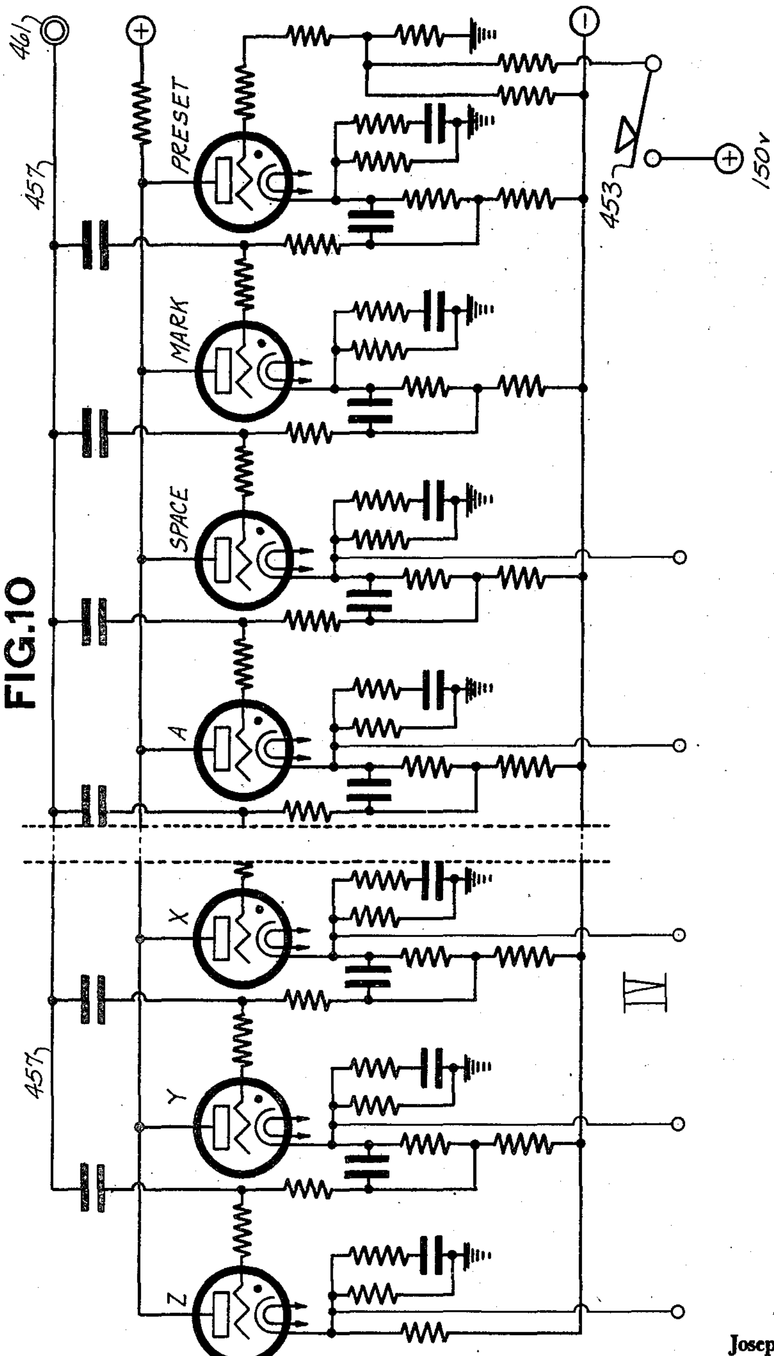
FIG. 9



Joseph R. Desch
Robert E. Mumma and
Ernest V. Gulden
Inventors

By Earl Beust
Their Attorney

FIG. 10



Joseph R. Desch
Robert E. Mumma and
Ernest V. Gulden
Inventors

By Earl Bennett
Their Attorney

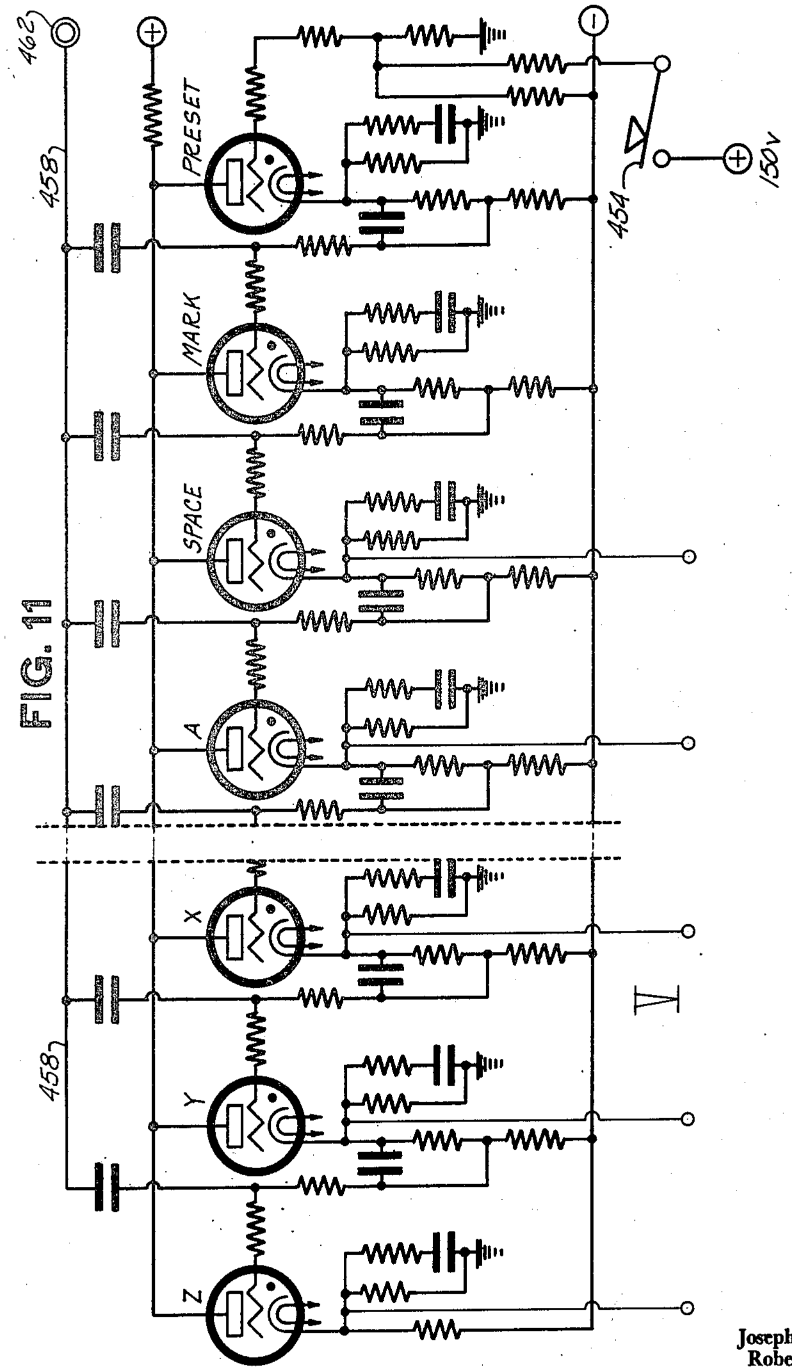


FIG. 11

Joseph R. Desch
Robert E. Mumma and
Ernest V. Gulden
Inventors

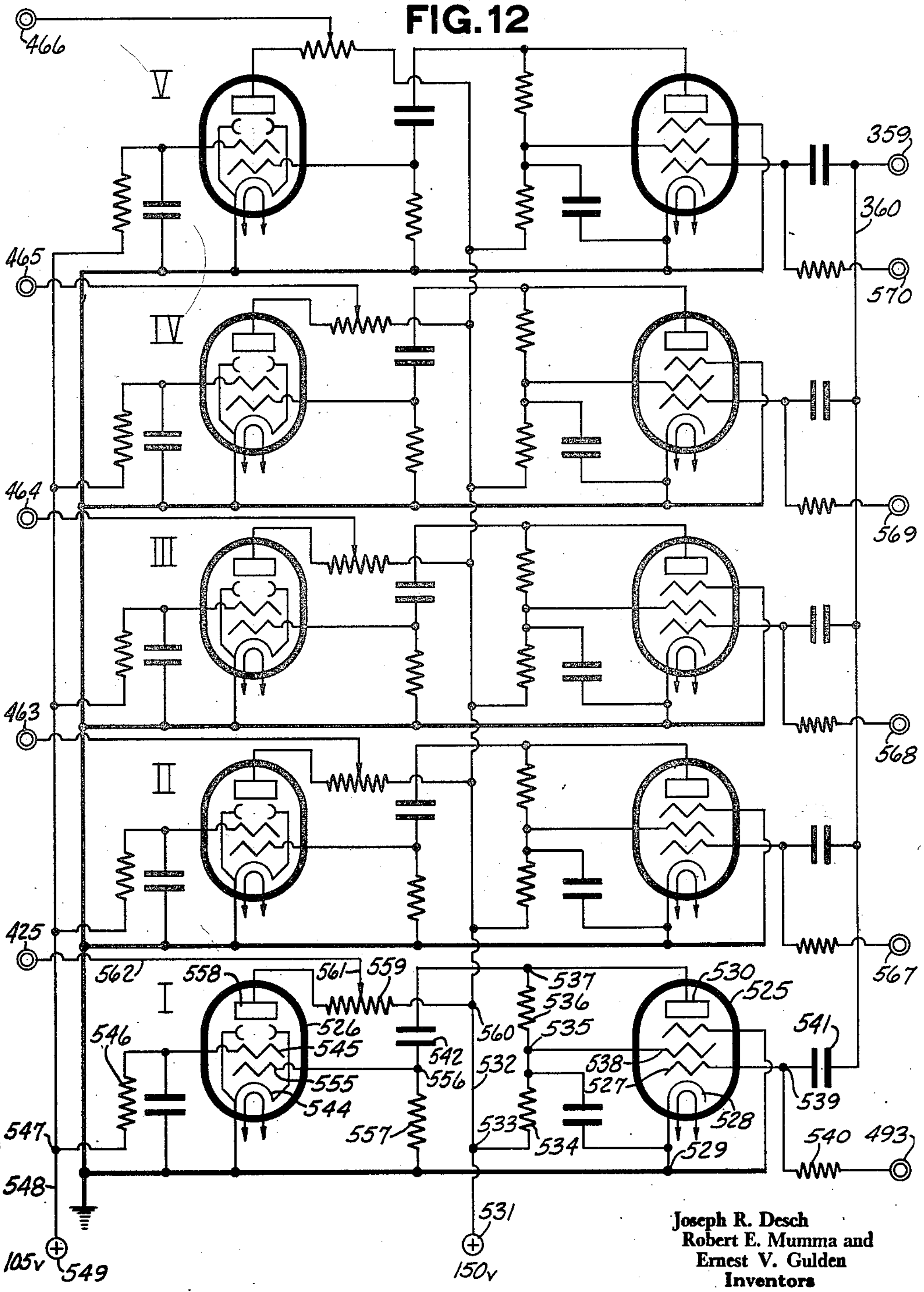
By Karl Benst
Their Attorney

Aug. 12, 1947. J. R. DESCH ET AL 2,425,307

COMMUNICATION SYSTEM

Filed Sept. 16, 1942 14 Sheets-Sheet 12

FIG. 12



Joseph R. Desch
Robert E. Mumma and
Ernest V. Gulden
Inventors

By Carl Beust
Their Attorney

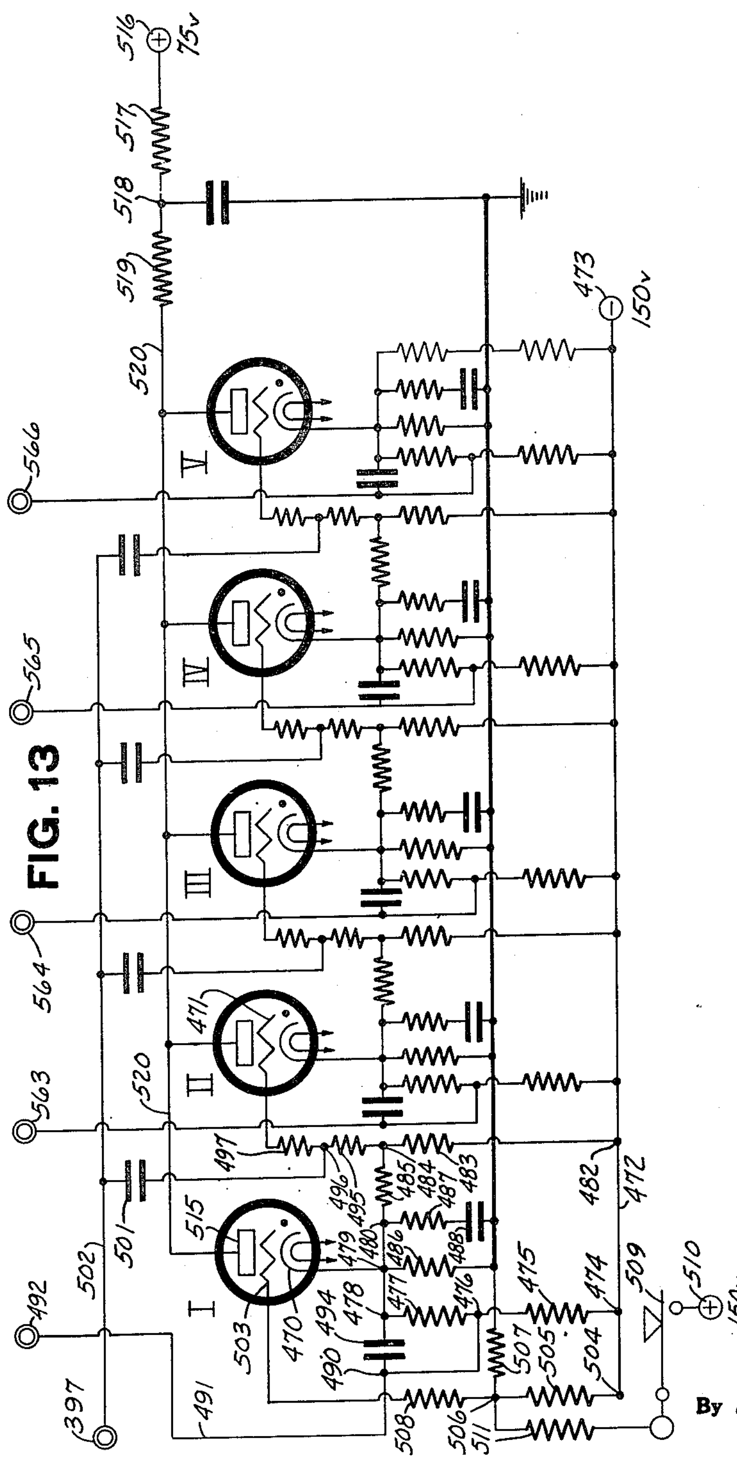


FIG. 13

Joseph R. Desch
Robert E. Mumma and
Ernest V. Gulden
Inventors

By Carl Beust
Their Attorney

FIG. 14

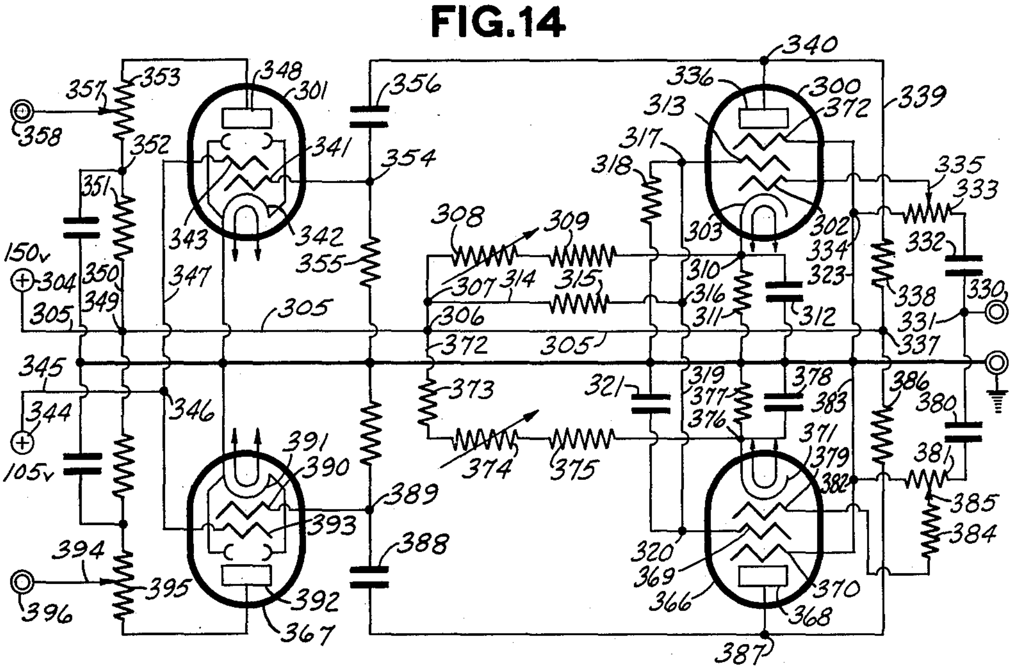
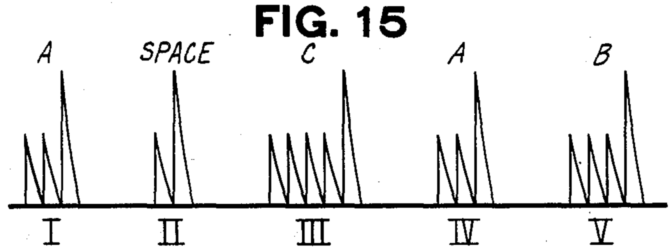


FIG. 15



Joseph R. Desch
Robert E. Mumma and
Ernest V. Gulden
Inventors

By Earl Benot
Their Attorney

Patented Aug. 12, 1947

2,425,307

UNITED STATES PATENT OFFICE

2,425,307

COMMUNICATION SYSTEM

Joseph R. Desch, Ernest V. Gulden, and Robert E. Mumma, Dayton, Ohio, assignors to The National Cash Register Company, Dayton, Ohio, a corporation of Maryland

Application September 16, 1942, Serial No. 458,546

13 Claims. (Cl. 177—353)

1

This invention relates to communication systems and is directed particularly to a system in which various symbols making up the data to be transmitted are transformed into bursts or trains of discrete rapidly recurring signals, the number of signals in each burst being dependent upon the symbol which it represents. The bursts representing the different symbols are sent one after another over a single communication channel, and a marking signal is provided for each burst to indicate the completion of the burst. The marking signal is used to control a receiving apparatus to govern the allocation and storage of the symbols therein. The signals by which the symbols may be represented may take various forms, as, for instance, interruption or modulation of a continuous carrier wave and/or discrete rapidly recurring impulses, or representations thereof.

The sending apparatus is provided with means for generating the bursts of signals and controls the number of signals in each burst according to the symbol being sent. The signals can be transmitted by any convenient means; for instance, over a wire or by radio to a receiving and storing apparatus, where they are transformed back into single representations of the symbols and are stored.

The receiving apparatus contains a plurality of transforming and symbol-storing means, each consisting of a group of devices, which transforming and symbol-storing means may be selectively and successively rendered effective under control of the marking signals to receive the symbol-representing signals and which devices of a group represent the symbols and are differentially operated according to the number of signals in a burst to transform the signals back into a single or direct representation of the symbol and to store this representation.

The receiving apparatus 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 sending and receiving apparatus either before or during a transmitting operation.

High-speed communication of data is obtained with applicants' novel arrangement because the sending and receiving apparatus can generate and respond to the signals at a high frequency and because the signal bursts which are used to represent the various symbols 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 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 transmitting data.

2

It is an object of the invention, therefore, to provide novel high-speed means for sending and receiving data in the form of bursts of different numbers of signals.

A further object of the invention is to provide a means for producing bursts of signals, each burst comprising a predetermined number of symbol-representing signals followed by a control signal.

A further object of the invention is to provide a novel means for transforming a data-representing symbol into a number of discrete rapidly-recurring signals.

A further object of the invention is to provide a means to transform any data-representing symbol into a signal train comprising a number of discrete signals of one type for indicating the symbol and a control signal of another type for indicating the end of the signal train.

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 like discrete signals representing the symbols and are sent out over a single communication channel.

A further object of the invention is to provide a means to transform a plurality of data-representing symbols into bursts or individual trains of different numbers of discrete signals corresponding to the symbols, with a marking signal included in each burst to distinguish the bursts.

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

A further object of the invention is to provide a receiving means for receiving bursts of signals consisting of signals having one characteristic and signals having a distinctive characteristic, and having discriminating means to distinguish between the signals having different characteristics and to control the receiving means accordingly.

A further object of the invention is to provide a means for receiving and transforming bursts of symbol-representing signals into direct representations of the various symbols, each of said bursts containing a number of similar discrete signals and a control signal, and said receiving means containing a plurality of transforming means for setting up direct representations of the various symbols according to the number of signals in a burst and a routing means controlled by the control signals to route the bursts to the different 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 a 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 controlling 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 controlling the sending of five symbols in succession.

Fig. 6 shows the start and stop controls for the sending apparatus, and also shows the means for forming the symbol-representing impulses and the marking signals.

Figs. 7 to 11 inclusive show portions of the transforming and symbol-storing means in the receiving apparatus, which means consists 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. 12 shows relay means for selectively directing or routing impulses to the various groups of transforming and symbol-storing means.

Fig. 13 shows a routing control device containing a plurality of sequentially operable tubes which are controlled by the marking 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.

Fig. 14 shows means in the receiving apparatus for discriminating between symbol-representing impulses and marking impulses and controlling the receiving apparatus according to the significance of the impulses.

Fig. 15 shows five bursts which may be transmitted in succession and illustrates the general character of the trains of signals by which the symbols are transmitted.

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 letters of the alphabet.

For the purposes of this disclosure, the signals by which the symbols are represented will consist of discrete rapidly recurring impulses, 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 a "space" symbol and the letters A to Z 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 marking impulse tube and a shift tube.

The tubes of each bank control the number of impulses which will be in a burst and are connected in a chain to be fired automatically one after another in sequence, beginning with any selected symbol-representing control tube in the chain and continuing through the marking impulse tube to the shift tube. The depressed key in any bank selects the starting point in the firing sequence by preparing its related symbol-representing control tube to be fired in response to an impulse commonly impressed on all of the symbol-representing control tubes. 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 control 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 utilized to control the output of a small-amplitude impulse generating tube which sends out a small-amplitude impulse to the receiving apparatus each time one of the symbol-representing control tubes is fired.

When the last symbol-representing control tube in a chain is fired, it causes the marking impulse tube to fire. The marking impulse tube sends an impulse to control a second impulse generating tube, which sends to the receiving apparatus an impulse having a larger amplitude than the impulses sent out under control of the symbol-representing control tubes. The impulses from the small and large-amplitude impulse-generating tubes are impressed on a single output conductor and may be sent to the receiving apparatus.

The marking impulse tube, when it is fired, causes the shift tube of this bank to be fired and send an impulse to the symbol-representing control tubes of the next bank of the tubes to fire the prepared symbol-representing control tube therein and start 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 this successive operation of the banks of tubes enables the symbol-representing control tubes of all the banks to control the same small-amplitude impulse-generating tube, and the marking impulse tubes of all the banks to control the same large-amplitude impulse-generating tube so that the impulses representing the different symbols can be sent in succession over a single communication channel. The output from these generating tubes will therefore consist of bursts of rapidly recurring impulses for each bank of tubes, each burst being made up of a series of small-amplitude impulses followed by a large-amplitude impulse.

It is clear that the invention is not limited to the use of small-amplitude impulses as the plurality of signals, and large-amplitude impulses as terminal signals, because the large-amplitude impulses could obviously be used to make up the plurality of signals, and the small-amplitude impulses could be used as terminal signals.

A delay is provided in the firing of the shift tube of each bank by its related marking impulse tube. This delays the initiation of the firing of the tubes of the next bank and provides a space or time interval between the successive bursts.

After the symbols have been set up on the keys, transmission of the symbols is initiated by operating a start key, which causes a firing impulse to be sent to the symbol-representing control 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 a discriminating means which receives the impulses and is capable of distinguishing between the small-amplitude and the large-amplitude impulses; a routing means; and a plurality of transforming and symbol-storing means consisting of groups or banks of gaseous electron tubes for transforming the bursts of impulses into single representations of the symbols and storing the symbols.

Each group or bank of transforming and symbol-storing tubes contains a tube representing each symbol, a tube corresponding to the marking impulse, and a pre-setting tube. The marking impulse and 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 marking impulse tube, then the space symbol tube, and next the tubes for the symbols A to Z, 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 in connection with the sending apparatus, 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 line to the various banks of transforming and 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 marking 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 line 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 take other forms, such as a sequence switch which is capable of step-by-step operation to relay the impulses to the various banks.

The discriminating means in the receiving apparatus receives all the impulses which are sent from the sending apparatus and includes means which is responsive to both small- and large-amplitude impulses and means which is only responsive to the large-amplitude impulses. The means which is responsive to all the received impulses passes these impulses to a 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. The means which is responsive to the large-amplitude impulses only is effective to send an impulse to the routing control tubes to cause one of these tubes to be fired each time a large-amplitude impulse is 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 marking impulse tube in its bank of tubes to be responsive to signal impulses and will continue to be conductive until signal symbol impulses are relayed to that bank and cause the marking impulse 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 large-amplitude impulse to be received.

The receiving device is now ready to receive signals. As the first burst of impulses is received, the small and large-amplitude impulses will be passed on to the common impulse line and relayed from the common impulse line 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. The marking impulse, or large-amplitude impulse, which is the last impulse of the burst, will also be effective, through the discriminating means, to cause an impulse to be sent 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 in response to the marking impulse of the burst, 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 marking 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, the last or marking impulse of this burst will cause the firing of the next routing control tube and prepare the next transforming and symbol-storing bank for reception of the next burst of impulses. In this way, the successive bursts of impulses are routed to the various banks of symbol-storing tubes and control the setting of the various symbols therein.

After the sequence of bursts have 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 communication system for sending and receiving data 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. Fig. 15 shows, in a general way, a train of impulses made up of the bursts of impulses which would be used to transmit the symbols for "A," "Space," "C," "A," and "B."

A consideration of these bursts shows that the "space" symbol is represented by a burst containing one small-amplitude symbol-representing impulse followed by a large-amplitude marking impulse; the letter "A" is represented by a burst containing two small-amplitude impulses and a large-amplitude impulse; and the letter "B" is represented by three small-amplitude impulses and a large-amplitude impulse. In the instant embodiment, this relation between the various letters and the number of small-amplitude impulses extends to the letter "Z," which would be represented by twenty-seven small-amplitude impulses and a large-amplitude impulse.

The form of the impulses as shown in this figure is one form which may be used, but the invention may be carried out with other forms of impulses just as long as a distinction is maintained between the variable number of impulses

and the marking or controlling impulses. 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 sending and receiving apparatus which deal with 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 control means which controls the transformation of the symbols into different numbers of impulses. 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.

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 according 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. The 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. The tubes making up the bank fall into three classifications—namely, symbol-representing control tubes; a marking impulse tube; and a shift tube.

As many symbol-representing control tubes will be included in each bank as there are symbols which may be selected for transmission, and these tubes will control the creation of different numbers of impulses by which the symbols are represented. In the present embodiment, each group will include a tube for a "space" symbol and one for each of the letters of the alphabet, though in Fig. 1 only the "Space," "A," "B," "Y," and "Z" tubes are shown, the symbol-representing control tubes for the leters "C" to "X" inclusive having been omitted to simplify the showing of the bank because the circuits for these tubes ar identical with those of other symbol-representing control tubes and the operation of the symbol-transforming means can be readily understood without a showing of them.

One marking impulse tube "Mark" is provided for the bank and is operated to control the creation of a marking impulse for indicating the end of a burst after the symbol-representing control tubes of the bank have caused the creation of control impulses.

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 control impulses after the marking impulse tube of one bank has operated to cause a marking impulse to be created to indicate the completion of the symbol-representing burst of impulses.

The circuits for supplying potential to the elements of the symbol-representing control 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 control tubes by means of parallel circuits, one for each tube, extending to ground from a negative potential supply conductor **61**, to which a negative potential of 150 volts is applied at terminal **62**. The circuit for the "A" tube is representative and extends from the supply conductor **61** at point **63** over resistor **64** of 150,000 ohms, point **65**, a resistor **66** of 75,000 ohms, points **67** and **68**, and over resistor **69** of 15,000 ohms and capacitor **70** of .002 microfarad in parallel, to ground.

The cathode **71** of the "A" tube is connected to this circuit at point **67** 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 potential 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 "Space" tube. From the point **65** in the cathode circuit for the "A" tube, the circuit extends through point **72**, over resistor **73** of 500,000 ohms, point **74**, a resistor **75** of 50.000 ohms, to the control grid **76** of the "Space" tube and provides this grid with a negative biasing potential of approximately 56 volts. This connection between the cathode 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 "Z" tube is the first tube in the sequence, the control grid **77** 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 line **61**, over point **78**, resistor **79** of 150,000 ohms, point **80**, and resistor **81** of 90,000 ohms to ground, to which circuit the grid **77** is connected from point **80** over resistor **82** of 500,000 ohms, point **83**, and resistor **84** of 50,000 ohms.

Each control grid of the symbol-representing control tubes is electrostatically connected to a starting impulse conductor **90**, the connection for the grid **76** of the "Space" tube extending from point **74** in the grid circuit, over a capacitor **91** of 10 micro-microfarads to the conductor **90**. The starting impulses, which are positive potential impulses impressed on conductor **90**, 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 starting 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 starting 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 control tubes by a circuit which extends from terminal **92** (Fig. 6), upon which is impressed a positive potential of 105 volts, and continues over conductor **93**, point **94**, conductor **95**, points **96** and **97**, a resistor **98** of 500 ohms, point **99**, a resistor **100** of 3,000 ohms, point **101**, and conductor **102** to the common anode potential supply terminal **103** for the symbol-representing control tubes.

Point **99** in this circuit is connected to ground over a capacitor of 0.1 microfarad, which absorbs the shock of any abrupt potential application or change in the circuit.

Terminal **103** is connected to terminal **104** (Fig. 1), to which is connected an anode potential supply conductor **105** for the symbol-representing control tubes of this bank. Each of the anodes of the symbol-representing control tubes of this bank is connected over a resistor of 1,000 ohms to the anode potential supply conductor **105**, as, for instance, resistor **106**, over which the anode **107** of the "A" tube is connected to the anode potential supply conductor **105**.

When none of the symbol-representing control 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 **98**, **100**, and **106**.

At the moment one of these tubes is fired, its cathode will remain at a negative potential of 9 volts while the capacitor, as **70**, is charging, and, due to the resistance in the common anode potential supply circuit for the symbol-representing control 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 **105**, which drop provides a negative potential impulse on the conductor. As the anodes of all the symbol-representing control tubes of a bank are connected to the anode potential supply conductor **105**, a series of negative impulses will be impressed on the conductor as these tubes are fired one after another. These impulses are used to control a signal-generating tube **145** (Fig. 6), which, in a manner to be described later herein, creates symbol-representing impulses corresponding in number to those required to represent the symbol being transmitted.

The drop in the potential of the anode potential supply conductor **105** 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 control tubes, which includes the resistors **98** and **100**. The extinguishing action occurs because the potential of all the anodes of these tubes will drop as the potential of the anode supply conductor 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.

Negative potential is applied to the cathode

108 of the marking impulse tube "Mark" by means of a circuit similar to the ones for the symbol-representing control tubes, the circuit for the marking impulse tube extending from the negative potential supply conductor 61 at point 109, over resistor 110 of 150,000 ohms, point 111, resistor 112 of 75,000 ohms, point 113, and over a resistor 114 of 15,000 ohms and a capacitor 115 of .002 microfarad in parallel, to ground, to which circuit the cathode 108 of the marking impulse tube is connected at point 113. As in the case of the symbol-representing control tubes, the cathode of the marking impulse tube will acquire a positive potential when the tube is conducting.

Negative bias for the control grid 116 of the marking impulse tube is obtained by connecting the control grid to point 117 in the cathode potential supply circuit for the "Space" tube. This connection enables the potential rise of the cathode of the "Space" tube to be reflected on the grid of the marking impulse tube and cause the negative bias to be reduced below the critical point and the tube "Mark" to fire and become conducting automatically after the "Space" tube has become conducting.

The control grid of the marking impulse tube has no connection to the starting impulse conductor 90 and accordingly can be fired only when conduction occurs in the last symbol-representing control tube of the sequence, which in the instant embodiment is the "Space" tube.

The potential supply circuit for the anode of the marking impulse tube is similar to that for the symbol-representing control tubes. The circuit extends from the terminal 92 (Fig. 6), upon which is impressed a positive potential of 105 volts, conductor 93, point 94, conductor 95, point 96, resistor 118 of 500 ohms, point 119, resistor 120 of 4,000 ohms, point 121, and conductor 122 to common anode potential supply terminal 123 for the marking impulse tubes. Point 119 in this circuit is connected to ground over a 0.1 mircrofarad capacitor, which absorbs the shock of any abrupt application or change of potential in this circuit. Terminal 123 is connected to terminal 124 (Fig. 1), to which is connected the anode 125 of the marking impulse tube of this bank. The anode 125 will have a normal positive potential of 105 volts, but, due to the resistance in the common anode potential supply circuit, this potential will drop as the tube is fired and will fluctuate in a manner similar to that described above for the symbol-representing control tube; namely, drop to a positive potential of about 6 volts while capacitor 115 is charging and then rise to about 85 volts as long as the tube is conducting. The potential drop which occurs while the capacitor 115 is charging provides a negative potential impulse which is used to control a signal-generating tube 146 (Fig. 6) for creating a marking signal in a manner to be described later herein. This impulse, which occurs at the moment the marking impulse tube is fired, can also cause any other tube which is connected to the common anode potential supply circuit for the marking impulse tubes, over resistors 118 and 120, to be extinguished. It should be noted that, since the symbol-representing control tubes have a different anode potential supply circuit from the marking impulse tube, the firing of the marking impulse tube will not be effective to extinguish the last symbol-representing control tube of the sequence which has been fired and is conducting.

The cathode 126 of the shift tube is connected to ground from point 127 over a resistor 128 of 15,000 ohms and capacitor 129 of .002 microfarad in parallel. The cathode, therefore, is normally at ground potential, but, when the tube becomes conducting, the potential of the cathode rises due to the resistor 128. A conductor 130 extends from the cathode circuit at point 127 to the terminal 131 to enable the potential rise of the cathode 126 to be used as a starting impulse for starting the firing of symbol-representing control tubes in bank II.

The control grid 132 of the shift tube obtains its negative bias from the cathode potential supply circuit for the marking impulse tube. The connection is from point 111 in the cathode potential supply circuit of the marking impulse tube and over point 133 and resistor 134 of 500,000 ohms to the control grid 132. The potential rise of the cathode of the marking impulse tube, when that tube is conducting, is effective to reduce the negative bias on the control grid 132 and cause the shift tube to fire and become conducting. A capacitor 135 of .001 microfarad is connected between point 133 in this circuit and ground to delay potential rise of the control grid 132 and the consequent firing of the start tube after the firing of the marking impulse tube. This provides a time interval between bursts, which interval may be made longer or shorter as desired by varying the capacity of capacitor 135.

Potential is supplied to the anode 136 of the shift tube by a circuit which starts at the terminal 137 (Fig. 6), which has a positive potential of 150 volts impressed thereon, and continues over conductor 138, point 139, resistor 140 of 500 ohms, point 141, and resistor 142 of 4,000 ohms to the common anode potential supply terminal 143 for the shift tubes. Point 141 in this circuit is connected to ground over a capacitor of 0.1 microfarad. Terminal 143 is connected to terminal 144 (Fig. 1), to which the anode 136 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 ground, the potential of the cathode, while the capacitor 129 is charging, and this potential drop will be effective to extinguish any previously conducting tube which derives its anode potential over the resistors 140 and 142 (Fig. 6) in the common anode potential supply for the shift tubes. Since the anodes of the marking impulse tube and the symbol-representing control tubes have different anode potential supply circuits from that of the shift tube, the firing of the shift tube will be ineffective to extinguish the marking impulse tube or the "Space" tube.

The sequential and automatic firing of the tubes of a bank always begins with a symbol-representing control tube and is initiated by a starting impulse. The control grids of the symbol-representing control tubes are electrostatically connected to the starting impulse conductor 90, but are normally sufficiently negatively biased so that a starting impulse impressed on the conductor will not be effective to reduce the bias below its critical point to cause the tubes to be fired and rendered conductive. In order that a starting 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 starting 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 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 is set up. Only the keys for the "Space" symbol and for the letters "A" and "Z" are shown, the keys for the letters "B" to "Y" 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 "A" key 150 (Fig. 1) is shown depressed, completing a priming circuit which starts at the terminal 153, upon which is impressed a positive potential of 105 volts, and continues over conductor 154 to point 155, closed key switch 156, conductor 157, and resistor 158 of 700,000 ohms to point 159 in the circuit by which negative biasing potential is supplied to the control grid of the "A" tube.

The application of positive potential by this circuit reduces the negative biasing potential of the control grid almost to its critical point, and, when the starting impulse is impressed on the tubes, the bias of the control grid of the "A" tube will be reduced 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 control 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 control of the formation of a burst of impulses corresponding to the first symbol to be transmitted is obtained, will now be explained.

The key 150 corresponding to the letter "A" has been depressed and completes the priming circuit for the "A" tube. A starting impulse is impressed on the starting impulse conductor 90 and causes the firing of the "A" tube. At the moment the "A" tube is fired, its anode potential will drop because of the resistor 106 and the resistors 98 and 100 in the symbol-representing control tube anode potential supply circuit, causing a drop to occur on the conductor 105, terminal 104, and terminal 103 of the anode potential supply circuit, which drop is used as an impulse to control the small-amplitude impulse generating tube 145. The potential of the cathode of the conducting "A" tube will rise and, through the connection between point 65 in its potential supply circuit and the control grid 76 of the "Space" tube, will cause the potential of the control grid 76 to rise and reduce the bias below its critical value and cause the 'Space" tube to fire and become conducting. The potential of the anode of the "Space" tube will drop and cause another impulse on conductor 105, terminal 104, and terminal 103 in the anode potential supply circuit, which impulse will also control the small-amplitude impulse generating tube 145 and in addition will also extinguish the conducting "A" tube. The potential of the cathode of the "Space" tube will rise and cause the potential of the grid 116 of the marking impulse tube "Mark" to rise, reducing its bias below its critical value and causing the marking impulse tube to fire and become conducting.

When the marking impulse tube is fired, the potential of its anode will drop, which drop occurs at the terminal 124 and terminal 123 and is used as an impulse to control the large-amplitude generating tube 146 (Fig. 6). The potential drop of the anode of the marking impulse tube will not be effective to extinguish the "Space" tube, because the anodes of these tubes are in different anode potential supply circuits. The potential of the cathode of the marking impulse tube will rise when the tube becomes conductive and, through the connection extending from point 111 in its cathode potential supply circuit, will cause the potential of the control grid 132 of the shift tube to rise and reduce the grid bias below its critical value. There is a slight delay in the potential change on the control grid 132, due to the capacitor 135, which connects the point 133 in this circuit to ground.

When the shift tube fires, there will be a potential drop in its common anode supply circuit, due to the resistors 140 and 142. However, this drop will not be effective to extinguish the marking impulse tube or the "Space" tube, because their anodes are included in different anode potential supply circuits. The potential rise of the cathode 126 of the shift tube 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 103 for controlling the small-amplitude impulse generating tube 145, and these impulses will be followed by an impulse at the terminal 123 to control the large-amplitude impulse generating tube 146. After the signal generating control impulses have been provided, an impulse will be impressed on the terminal 131, which is used to start the firing of 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, the marking impulse tube, and the "Space" 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 control the sending of 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 form the controls for the sending of five symbols are as follows:

Each of the negative potential supply conductors 161, 162, 163, and 164 for the banks "II," "III," "IV," and "V" is connected, respectively, to a terminal as 165, 166, 167, and 168, upon which is impressed a negative potential of 150 volts.

The symbol-representing control tube anode potential supply conductors 169, 170, 171, and 172 for banks "II," "III," "IV," and "V" have their terminals 173 174, 175, and 176 connected to the common supply terminal 103 (Fig. 6), so that these supply conductors for all the banks will be connected together at the terminal 103 and from this terminal will be connected over the common resistors 98 and 100 to the source of potential. In this network, the firing of any symbol-representing control 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 "Space" tube, which remains conducting when the operation in the first bank is completed, is extinguished by the firing of the first symbol-representing control 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 103 which drop can be used to control the signal generating tube 145 to create a small-amplitude impulse.

In a similar manner, the anodes of the marking impulse tubes for the various banks have their terminals 177, 178, 179, and 180 connected to the common anode potential supply terminal 123 (Fig. 6) for the marking impulse tubes. As a marking impulse tube in the various banks is fired, the potential drop of its anode will cause the potential of the anodes of the other marking impulse tubes to drop and extinguish any previously conducting marking impulse tube, so that the marking impulse tube of the first bank will be extinguished when the marking impulse tube of the second bank is fired. The potential drop of any anode will also control the signal-generating tube 146 to create a large-amplitude impulse.

The anodes of the shift tubes of the various banks are all connected to the common anode potential supply circuit by having the terminals 181, 182, 183, and 184 (Figs. 2, 3, 4, and 5), to which they are connected, connected with the terminal 143 (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 starting impulse conductor of a bank connected to the cathode of the shift tube of the bank previously operated. The terminal 131 (Fig. 1), which is connected to the cathode 126 of the shift tube of the first bank, is also connected to the terminal 185 (Fig. 2), to which the starting impulse conductor 186 of the second bank is connected, so that the potential rise of the cathode 126, as the shift tube is fired, can be impressed on the starting impulse conductor 186 of the second bank to fire any primed symbol-representing control tube therein and initiate the sequential firing of the tubes of the second bank. The terminal 187, which is connected to the cathode of the shift tube of the second bank, is similarly connected to the terminal 188 (Fig. 3), to which the starting conductor 189 of the third bank is connected. The terminal 190 (Fig. 3) is connected to the terminal 191 (Fig. 4) to start the sequential operation in the fourth bank, and terminal 192 (Fig. 4) is connected to terminal 193 (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 control impulses for the five bursts can be formed automatically in succession.

Each of the banks has a key bank similar to the one shown in Fig. 1 for selectively closing priming circuits to the symbol-representing control tubes.

Signal generating means

The signal generating means consists of two normally conducting vacuum tubes 145 and 146 (Fig. 6), which can be controlled to create the small- and large-amplitude impulses by which symbols are sent from the sending apparatus to the receiving apparatus.

The small-amplitude impulse generating tube 145 is controlled from the symbol-representing control tubes and is effective to impress a small-amplitude positive impulse on a signal output terminal of the sending apparatus each time one of the symbol-representing control tubes in any bank fires and becomes conducting. Similarly, the large-amplitude impulse generating tube 146 is controlled from the marking impulse tubes and is effective to impress a large-amplitude positive impulse on the signal output terminal of the sending apparatus each time a marking impulse tube in any of the banks fires and becomes conducting.

Obviously the control of the small- and the large-amplitude impulse generating tubes 145 and 146 could be reversed to enable the symbol-representing control tubes to control the large-amplitude impulse generating tube 146 and the marking impulse tubes to control the small-amplitude impulse generating tube 145, thereby to produce bursts of impulses containing different numbers of large-amplitude impulses followed by a small-amplitude impulse.

The various elements of these tubes, except the control grids, have similar connections. The cathodes 200 and 201 (Fig. 6) for the tubes 145 and 146, respectively, are connected to ground, as are the suppressor grids 202 and 203. The anodes 204 and 205 are supplied with positive potential by a circuit starting from terminal 137, which has a positive potential of 150 volts applied thereto, and continuing over conductor 138, point 139, resistor 206 of 250 ohms, point 207, resistor 208 of 2,500 ohms, point 209, and conductor 210 to the anodes 204 and 205, to which conductor 210 is also connected the signal output terminal 211 for the sending apparatus. Point 207 in the anode circuit is connected to ground over a capacitor of .1 microfarad to absorb any shock resulting from an abrupt application or change of potential in this circuit. As both tubes are normally conducting, their anodes will have a positive potential of approximately 40 volts due to the resistors in their anode circuit. However, when the current in either tube is reduced, the potential of the anodes will rise toward 150 volts, depending upon the extent of the reduction in the current in the tube. The screen grids 216 and 217 for these tubes are connected together and over point 218, resistor 219 of 250 ohms, points 97 and 96, conductor 95, point 94, and conductor 93 to terminal 92, which has applied thereto a positive potential of 105 volts.

The difference in the amplitude of the impulses which are obtained from these tubes is due to the control exerted by their control grids. Control grid 220 for the small-amplitude impulse generating tube 145 is given a zero bias by means of a circuit which extends from the adjustable potential divider 221 over point 222, resistor 223 of 10,000 ohms, and point 224 to the grid 220. Point 222 is connected to ground over a capacitor of 8 microfarads to absorb the shock of any abrupt change of potential in this circuit. Control grid 225 for the large-amplitude impulse generating tube 146 is given a zero bias over a similar circuit extending from the potential divider 226; however, the bias on this grid is adjusted to have a lower positive threshold than the grid 220 of the tube 145.

The terminal 103 (Fig. 6), upon which negative potential impulses are impressed as the symbol-representing control tubes are fired, is connected over conductor 102, point 101, and a capacitor 227 of 10 micro-microfarads to point 224, to which the control grid 220 is connected. By this connection, these negative impulses are able to reduce the current through the tube 145 to a degree which will, due to the resistors 206 and

208 in the anode potential supply circuit, cause the potential of the anode 204 to rise and provide a small-amplitude positive potential impulse on the output terminal 211.

The terminal 123, upon which the negative impulses are impressed as the marking impulse tubes are fired, is connected over conductor 122, point 121, and a capacitor 228 of 20 micro-micro-farads to point 229, to which the grid 225 of the tube 146 is connected. Due to the fact that the grid of this tube is adjusted to have a positive threshold of less value than the grid 220 of the tube 145, these negative impulses have a greater effect on the grid and will cause the grid 225 to reduce the current in the tube 146 to a smaller amount than was the case with tube 145, and, due to the resistors 206 and 208, the potential of the anode 205 will rise a greater extent and provide a large-amplitude positive potential impulse on the output terminal 211.

In the above manner, the negative potential impulses which result from the firing of the symbol-representing control tubes and marking impulse tubes are used to control the creation of the positive potential impulses of different amplitudes which make up the bursts sent from the sending apparatus 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 control tubes, the transmission of these symbols is initiated by momentary depression of the start key 230 (Fig. 6), which closes the energizing circuit for the starting relay 231. The circuit extends from the terminal 232, upon which may be impressed any desirable positive potential, to the point 233, thence over the contacts 234 closed by the key 230, point 235, and over the winding of the starting relay 231 to ground. When the starting relay 231 is energized by the start key 230, it closes a holding circuit for itself from terminal 232, point 233, normally closed contacts 236, contacts 237 closed by the starting relay, point 235, and over the winding of the starting relay 231 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 236 are opened by the energization of the stop relay 238, in a manner to be explained hereinafter, to terminate a transmitting operation.

The starting relay 231 also closes contacts 239 to cause the firing of a start tube 240, which sends a starting impulse to the starting impulse conductor 90 (Fig. 1) of the first symbol-transforming bank.

Starting tube 240 (Fig. 6) has its cathode 241 connected to ground over a resistor 242 of 15,000 ohms. Before the starting relay is energized, the control grid 243 of the starting tube is given a negative potential bias of 150 volts by means of a circuit which starts at the terminal 244, upon which is impressed a negative potential of 150 volts, and continues over point 245, conductor 246, resistor 247 of 500,000 ohms, point 248, and resistor 249 of 500,000 ohms to the grid 243. The anode 250 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 248 in the grid circuit, over a resistor 251 of 300,000 ohms, conductor 252, point 253, and resistor 254 of 2,500 ohms.

When the starting relay 231 closes its contact 239, positive potential is applied to the anode 250 over a circuit which starts at the terminal 92, upon which is impressed a positive potential of 105 volts, and continues over conductor 93, point 94, conductor 95, point 96, conductor 260, contacts 239, point 261, resistor 262 of 250 ohms, point 253, and resistor 254. When the positive potential is applied to the anode 250 by the closing of the contacts 239, the circuit from point 253 to point 248 in the grid circuit causes the positive potential to be applied to the grid 243 and causes its potential to change from 150 volts negative to 9 volts positive. The application of positive potential by the closing of the contacts 239 has caused the anode 250 of the start tube to acquire a positive potential and the grid 243 to become more positive than the cathode 241, which will cause the start tube 240 to fire and become conducting.

Resistor 242 in the cathode circuit will cause the potential of the cathode 241 to rise when the tube 240 is conducting, and this rise is utilized as the starting impulse for the first bank of symbol-transforming tubes. The starting impulse is derived from a potential-tapping member 263 cooperating with the resistor 242 and enabling the amplitude of the starting impulse to be adjusted. Conductor 264 connects the potential-tapping member 263 to the terminal 265, which terminal is connected to the terminal 266 (Fig. 1), to which the starting impulse conductor 90 of the first bank of symbol-transforming tubes is connected.

After the transmission of the symbols has been initiated, the symbol-transforming banks will be operable one after another in sequence 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 267 (Fig. 6), which causes the termination of the transmission by energizing the stop relay 238 and thereby opening the holding circuit for the start relay.

The cathode 268 of the stop tube is at ground potential, being connected to ground over conductor 269. The grid 270 is given a negative biasing potential of 17 volts by being connected to a potential supply circuit which extends from terminal 244, which is supplied with a negative potential of 150 volts, and continues over point 245, conductor 271, resistor 272 of 150,000 ohms, point 273, resistor 274 of 20,000 ohms to ground over conductor 269. The grid 270 is connected over point 275 and resistor 276 of 500,000 ohms to the point 273 in the potential supply circuit.

A circuit extends from the point 275 over a capacitor 277 of 100 micro-microfarads to the terminal 278, which is connected to the terminal 279 (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 270, causing the stop tube to fire and terminate the transmission.

The anode 280 of the stop tube 267 has positive potential applied thereto when contact 239 is closed by the starting relay. The circuit extends from the terminal 92 and over the contacts 239 to the point 261, as explained above, and then continues over conductor 281, resistor 282 of 500 ohms, the winding of the stop relay 238, and conductor 283 to the anode 280. Until the stop tube fires and becomes conducting, there will be no current in the circuit which includes the winding of the stop relay 238; however, as soon as the tube is fired and becomes conducting, current will flow through the winding of the stop relay 238, which will be energized and will open the contacts 236. The contacts 236 will break the holding circuit for the start relay 231, which will be deenergized and will open contacts 237 and 239. Contact 237 will also interrupt the holding circuit for the start relay 231 to prevent its reenergization when the contacts 236 close as the stop relay is deenergized. Contacts 239 open the anode circuit for the start and stop tubes, extinguishing these tubes and deenergizing the stop relay.

The operation of the stop tube 267, therefore, causes the termination of the transmitting operation and restores the starting controls to the condition which existed prior to the operation of the start key 230.

Receiving Apparatus

The five bursts of positive potential impulses which are impressed on the signal output terminal 211 of the sending apparatus during a transmitting operation are transmitted to and impressed on a signal input terminal 330 (Fig. 14) 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 discriminating means which receives all the transmitted impulses and is capable of distinguishing between the small-amplitude impulses and the large-amplitude impulses; 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; and routing means which is operated each time a large-amplitude or marking impulse is received and is effective to route the successive bursts into different transforming and symbol-storing means.

Discriminating means

The discriminating means is shown in Fig. 14. All of the signals which are impressed on the input terminal of the receiving apparatus are effective to control the discriminating means, which responds differently to the small-amplitude and the large-amplitude impulses.

Part of the discriminating means is responsive to both the small-amplitude and the large-amplitude impulses which are received and is capable of impressing a like number of impulses on a common impulse conductor in the receiving apparatus.

Another part of the discriminating means is responsive only to the large-amplitude or marking impulses and is effective to send an impulse to a routing control device to cause an operation thereof each time a marking impulse is received. This part of the discriminating means detects the large-amplitude marking impulse which indicates the end of a burst and causes the routing means to route the next burst to another symbol-storing group of tubes.

The part of the discriminating means which is responsive to all the received impulses consists of a pair of vacuum tubes 300 and 301 (Fig. 14), of which the tube 300 is affected by all the positive potential impulses which are received from the sending apparatus, and the tube 301 is controlled by the tube 300 and serves to change the phase of, and amplify, a series of potential impulses formed by the operation of the tube 300 and to impress the amplified impulses on a common impulse conductor in the receiving apparatus.

Tube 300 is normally non-conducting because of the bias on its control grid 302, but is rendered conducting each time a positive potential impulse is impressed on the control grid.

The potential supply circuit for the cathode 303 of the tube 300 starts at terminal 304, upon which is impressed a positive potential of 150 volts, and continues over conductor 305, points 306 and 307, the variable resistor 308 of 10,000 ohms, resistor 309 of 5,000 ohms, point 310, and over the resistor 311 of 1,000 ohms and capacitor 312 of .1 microfarad in parallel to ground. The cathode 303 is connected to point 310 and may be given a positive potential of from 9 to 25 volts, depending upon the adjustment of the resistor 308. The screen grid 313 also derives its potential from terminal 304 by means of a circuit which is the same as the circuit traced above to point 307 and then extends over conductor 314, resistor 315 of 10,000 ohms, points 316 and 317, and over resistor 318 of 25,000 ohms to ground. The screen grid 313 is connected in this circuit at point 317 and is given a potential of 43 volts. A circuit also extends from point 316, over conductor 319, point 320, and capacitor 321 of .1 microfarad to ground to absorb the shock of any abrupt application or change of potential in this circuit. The suppressor grid 322 is connected to ground over conductor 323.

The control grid 302 is connected to a circuit extending from the signal input terminal 330, over point 331, capacitor 332 of 250 micro-microfarads, resistor 333 of 10,000 ohms, and point 334 to ground over conductor 323. A potential-tapping member 335 cooperates with the resistor 333 to enable the grid 302 to be connected to this circuit. Control grid 302 is normally at ground potential and prevents conduction in the tube 300 until the positive impulse is impressed on the signal input terminal 330 and raises the potential of the grid 302 to allow conduction to take place in the tube.

The anode 336 of the tube 300 has a normal positive potential of 150 volts applied thereto over a circuit extending from terminal 304, conductor 305, point 337, resistor 338 of 15,000 ohms, conductor 339, and point 340. As the tube 300 becomes conducting, the potential of the anode 336 will drop, due to the resistor 338, and this potential drop is impressed on the control grid 341 of the tube 301 to control the conduction in that tube.

The potential of the cathode 303 and the effect of the input signal impulses on the control grid 302 can be regulated by the adjustable resistor 308 and the potential-tapping member 335, respectively, to enable the tube 300 to respond properly to both the small-amplitude and the large-amplitude positive impulses impressed on the signal input terminal 330.

The phase-changing and -amplifying tube 301 has a zero bias and is, accordingly, normally conducting. The cathode 342 of this tube is connected directly to ground. A positive potential of 105 volts is applied to the screen grid 343 of this tube by means of a circuit starting at terminal 344, upon which is impressed a positive potential of 105 volts, and continuing over conductor 345, point 346, and conductor 347.

The circuit by which potential is supplied to the anode 348 starts at terminal 304 and extends over conductor 305, point 349, conductor 350, resistor 351 of 500 ohms, point 352, and resistor 353 of 5,000 ohms to the anode 348. Since the tube is normally conducting, its anode 348 will be at approximately 50 volts due to the resistors 351 and 353 in the anode circuit. However, this potential will rise toward 150 volts as the conductivity in the tube is reduced by the control grid 341.

The control grid 341 is normally at ground potential, being connected to ground over point 354 and resistor 355 of 10,000 ohms. Point 354 in this circuit is electrostatically connected, through a capacitor 356 of 200 micro-microfarads, to the point 340 in the anode circuit for the tube 300, which connection enables the negative potential impulses caused by the conduction in tube 300 to be impressed on the control grid 341 to reduce conduction in tube 301.

A potential-tapping member 357 cooperates with the resistor 353 in the anode potential supply circuit for tube 301 and enables the positive potential rise in this circuit, because of the potential rise of the anode 348, to be impressed on the common impulse conductor 360 (Fig. 12) in the receiving apparatus. The connection is from the current-tapping member 357 to the terminal 358, which terminal is connected to the terminal 359 (Fig. 12), to which the common impulse conductor 360 is connected.

This part of the discriminating means, therefore, is operated in response to both the small-amplitude and the large-amplitude impulses and impresses an impulse on the common impulse conductor 360 each time a small-amplitude impulse or a large-amplitude impulse is received at the signal input terminal 330.

The other part of the discriminating means also contains two vacuum tubes, 366 and 367, and is similar to the part described above. However, tube 366 is responsive to only the large-amplitude or marking impulses and controls the phase-changing and -amplifying tube 367 to cause an impulse to be impressed on an impulse conductor for a routing control device each time a large-amplitude impulse is received.

Tube 366 is normally non-conducting but is rendered conducting each time a large-amplitude impulse is impressed on the input terminal.

The potential-supplying circuits for the anode 368, the screen grid 369, and the suppressor grid 370 are similar to those given above for tube 300 and provide these elements with positive potentials of 150 volts and 43 volts and ground potential, respectively.

The cathode 371 is supplied with positive potential from terminal 304 by a circuit extending over conductor 305, point 306, conductor 372, resistor 373 of 15,000 ohms, adjustable resistor 374 of 10,000 ohms, resistor 375 of 5,000 ohms, point 376, and over resistor 377 of 5,000 ohms and capacitor 378 of .1 microfarad in parallel to ground. The cathode 371 is connected to this circuit at point 376 and has a positive potential of between 21 and 30 volts impressed therein, depending upon the adjustment of resistor 374.

The control grid 379 is connected to a circuit extending from the signal input terminal 330, over point 331, capacitor 380 of 250 micro-microfarads, resistor 381 of 10,000 ohms, point 382, and conductor 383 to ground. Control grid 379 is connected to this circuit over resistor 384 of 75,000 ohms and potential-tapping member 385 and is normally at ground potential.

The potential of the cathode 371 and the effect of the input signal impulses on the control grid 379 can be regulated by the adjustment of resistor 374 and the potential-tapping member 385, respectively, so as to prevent the small-amplitude impulses from affecting the tube and allow only the large-amplitude impulses to cause conduction to occur in the tube 366.

Whenever tube 366 is rendered conducting, the potential of its anode 368 will drop due to resistor 386 of 15,000 ohms in the anode potential supply circuit. A connection from point 387 in the anode potential supply circuit, over a capacitor 388 of 200 micro-microfarads to point 389, to which the control grid 390 of tube 367 is connected, enables the anode potential drop to control conduction in tube 367.

The phase-changing and -amplifying tube 367 of this part of the discriminating means also has a zero bias and is normally conducting. The circuits for supplying potential to the control grid 390, the cathode 391, the anode 392, and the screen grid 393 are similar to those explained above for corresponding elements of tube 301. Since the tube 367 is normally conducting, its anode will normally have a potential of approximately 50 volts due to the resistors in the anode circuit. Each time a large-amplitude impulse is impressed on the receiving apparatus, tube 366 will become conducting and, through the connection between points 387 and 389, will impress a negative impulse on the grid 390, causing the grid 390 of tube 367 to acquire a negative potential and reduce conduction in this tube, thereby causing the potential of the anode 392 to rise toward 150 volts. A potential-tapping member 394 cooperates with resistor 395 of 5,000 ohms in the anode circuit and enables the potential rise in this circuit, as conduction in the tube is decreased, to be used as a positive potential impulse. Terminal 396, which is connected to the tapping member 394, is also connected to terminal 397 (Fig. 13), to which is connected an impulse conductor for the routing control device upon which the positive potential impulses are impressed.

This part of the discriminating means can send an impulse to control the routing means each time a marking impulse is received.

The discriminating means as a whole, therefore, enables the different amplitudes of the input impulses to be utilized to provide different controls for the receiving apparatus.

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. 7 to 11, 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. 7, 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, a marking impulse tube "Mark," a space symbol tube "Space," and a tube for each of the letters "A" to "Z" inclusive, although in this figure the tubes for the letters "B" to "W" 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 marking impulse tube "Mark."

The marking impulse tube is not a symbol-representing tube but is included in the bank because a marking impulse is a part of every burst and the discriminating means impresses the marking impulse on the banks along with the different numbers of small-amplitude impulses, and it is therefore necessary to include this tube in the bank, so that the symbol-representing tubes will show the correct symbol at the end of a burst of impulses.

The tubes in the bank are connected for sequential firing beginning with the presetting tube, then the marking impulse tube, and next the tubes for the space symbol "Space" and the letters "A" to "Z," in that order, which, it will be noted, is the reverse order from the order in which the symbol-transforming control tubes in the sending apparatus are fired. The marking impulse tube and the symbol-storing tubes are fired one after another in response to impulses relayed to a firing impulse conductor from the common impulse conductor 360. 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 directly show the symbols stored in the various banks, can be used to control a remote indicating or recording apparatus, or can be used to directly transfer the symbols 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. 7) by means of parallel circuits, one for each tube, extending to ground from a negative potential conductor 400, to which a negative potential of 150 volts is applied at terminal 401. The circuit for the "Y" tube is representative and extends from the supply conductor 400 at point 402, over resistor 403 of 150,000 ohms, point 404, resistor 405 of 100,000 ohms, points 406, 407, and 408 and to ground over resistor 409 of 15,000 ohms in parallel with resistor 410 of 2,500 ohms and capacitor 411 of .001 microfarad in series. Cathode 412 of the "Y" tube is connected to this circuit at point 407 and has a negative potential of approximately 8 volts when the tube is not conducting. When the tube is conducting, the potential of the cathode 412 will rise to a positive potential of about 50 volts.

The "Z" 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 415 on the potential supply conductor 400, over resistor 416 of 250,000 ohms, points 417 and 418, and to ground over resistor 419 of 15,000 ohms in parallel with a resistor 420 of 2,500 ohms in series with a capacitor 421 of .001 microfarad. Cathode 422 of the "Z" tube is connected to this circuit at point 417.

The cathode potential supply circuits for all the tubes except the "Z" 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 423. The grid of the "Z" tube, for instance, is connected over resistor 426 of 50,000 ohms, point 427, resistor 428 of 500,000 ohms, point 429, and conductor 430 to point 404 in the cathode potential supply circuit for the "Y" tube, from which point it derives a normal negative biasing potential of 65 volts when the "Y" tube is not conducting. When the "Y" tubes becomes conducting and its cathode potential rises, it will cause the biasing potential of the grid of the "Z" tube to be reduced to almost its critical point, so that the "Z" tube can respond to the next firing impulse which is impressed on the bank. A capacitor 431 of 250 micromicrofarads connects point 429 in the grid circuit with point 406 in the cathode circuit to speed up the application of the potential rise on the grid of the "Z" tube when the "Y" tube becomes conducting.

The presetting tube "Preset," being the first tube in the series, does not have its control grid connected to a cathode potential supply circuit, but has a negative biasing potential of 64 volts supplied thereto by an equivalent circuit extending from point 432 on the conductor 400, over resistor 433 of 120,000 ohms, points 434 and 435, and resistor 436 of 90,000 ohms to ground, to which the control grid 437 is connected at point 435.

The grids of the tubes in the sequence from the marking impulse tube to the "Z" tube are electrostatically coupled to the firing impulse conductor by means of capacitors of 10 micro-microfarads, as capacitor 438, by which point 427 in the grid circuit of the "Z" tube is connected to the firing impulse conductor 423. The firing impulse conductor 423 extends from the terminal 424, and this terminal is connected to terminal 425 (Fig. 12) of the relay means which relays the impulses from the common impulse conductor 360 to this bank. The normal negative bias of the grids of these tubes will normally 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 439, which is connected over resistor 440 of 2,000 ohms to terminal 441, which has a positive potential of 75 volts applied thereto.

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 442. The circuit starts at terminal 443, upon which a positive potential of 150 volts is impressed, and continues over conductor 444, key 442, conductor 445, resistor 446 of 167,000 ohms, to point 434 in the circuit for the control grid 437. When this circuit is closed by the key 442, 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 closing the presetting key 442 before reception of data takes place. The firing of this tube extinguishes any previously conducting tube in the bank and primes the marking impulse tube, so that the first impulse of the burst which is relayed to the firing impulse conductor 423 of the bank will cause the marking impulse tube to be fired and become conducting. The firing of the marking impulse tube will extinguish the preset tube, and conduction in the marking impulse tube will prime the space symbol tube "Space." The succeeding impulses of the burst will fire the tubes "Space," "A," "B," "C," 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 potential of the cathode of this conducting tube will be positive, and this will be the only tube in the bank having its cathode at a positive potential. Conductors as 450, extending from the cathodes of the symbol-representing tubes, can be sensed by any suitable means for this condition 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 451, 552, 453, and 454 (Figs. 8, 9, 10, and 11), which 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 conductors 455, 456, 457, and 458 for the "II," "III," "IV," and "V" banks (Figs. 8, 9, 10, and 11) are connected to terminals 459, 460, 461, and 462, which terminals are connected to terminals 463, 464, 465, and 466, respectively (Fig. 12), 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 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, comprising 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 360 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 360 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. 13) 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 marking impulse is received. 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 360; and primes the next control tube in the sequence so that it will fire and become conducting when the next marking impulse is received.

Inasmuch as the marking impulses follow the small-amplitude impulses in a burst, 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. 13, 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 470 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 471 for the "II" control tube. The one branch extends from a negative potential supply conductor 472, to which a negative potential of 150 volts is applied at terminal 473, and continues over point 474, resistor 475 of 390,000 ohms, point 476, resistor 477 of 150,000 ohms, to points 478, 479, and 480. The other branch extends from the potential supply conductor 472 at point 482 and continues over resistor 483 of 300,000 ohms, point 484, and resistor 485 of 200,000 ohms to the points 479 and 480. From the points 479 and 480, the two branches continue to ground over resistor 486 of 15,000 ohms in parallel with resistor 487 of 2,500 ohms and capacitor 488 of .002 microfarad in series. The cathode 470 is connected at point 479 in this circuit and is given a negative potential of approximately 9 volts whenever the tube is not conducting. When the tube is conducting, the electron discharge 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 50 volts.

A circuit extends from point 476 in said one branch and continues over conductor 489, point 490, conductor 491, and terminal 492, which is connected to terminal 493 (Fig. 12) and supplies a negative biasing potential of about 50 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 470, due to conduction in the control tube, to be used to reduce the negative bias or "prime" the relay means.

A capacitor 494 of 50 micro-microfarads is connected between points 478 and 490 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 484 and continues over resistor 495 of 500,000 ohms, point 496, and resistor 497 of 50,000 ohms to grid 471 of the "II" control tube to supply this grid with a normal negative potential of about 65 volts. This circuit enables the "II" tube to be primed by having this negative potential reduced to 30 volts by the potential rise of cathode 470 when the "I" tube is conducting.

Grid 471 of the "II" tube is connected over point 496 and capacitor 501 of 10 micro-microfarads to an impulse conductor 502, which is connected to terminal 397, upon which is impressed a positive impulse by the discriminating means each time a marking impulse is received. These positive impulses will not be able to fire any of the tubes unless the tube which is to be fired has been primed.

The "I" tube is the first tube in the sequence, and its grid 503 can not derive its negative bias from the cathode potential supply circuit of a preceding tube. A circuit extending from point 504 on conductor 472, and over resistor 505 of 150,000 ohms, point 506, and resistor 507 of 100,000 ohms to ground, supplies grid 503 with a negative biasing potential of 60 volts over point 506 and resistor 508 of 500,000 ohms.

Since the routing control tubes are fired in response to marking impulses which occur after the small-amplitude impulses of the bursts, 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 509 (Fig. 13) can close a circuit starting from terminal 510, upon which a positive potential of 150 volts is impressed, and continuing over the key 509, resistor 511 of 167,000 ohms to point 506 in the circuit of grid 503. The application of this positive potential to the grid 503 will reduce the negative bias of the grid and 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 marking impulse of the first burst. The circuit closed by key 509 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 515 of the "I" tube by means of a circuit starting at terminal 516, upon which is impressed a positive potential of 75 volts, and extending over resistor 517 of 250 ohms, point 518, resistor 519 of 2,000 ohms, and conductor 520, to which anode 515 is connected. The anodes of the other tubes are also connected to conductor 520, 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 65 volts due to the resistors 517 and 519. Point 518 in this circuit is connected to ground over a capacitor of 8 microfarads to absorb the shock of an abrupt application 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 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. 12 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. 12 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 525 and 526, which constitute the means for relaying impulses from the common impulse conductor 360 to the first bank of transforming and symbol-storing tubes, are normally inoperative to relay the positive impulses from the common impulse conductor 360, because the control grid 527 of tube 525 is normally given a negative bias which the positive impulses cannot overcome. The tube 525 is "primed" by having the negative bias of its grid 527 reduced, and in this condition the tube can respond to the positive potential impulses on the common impulse conductor 360 and can cause the impulses to be relayed to the firing impulse conductor 423 for the first bank of transforming and symbol-storing tubes.

The cathode 528 of tube 525 is connected to ground over point 529. The anode 530 of this tube 525 is given a positive potential of 150 volts over a circuit starting at terminal 531, upon which is impressed a positive potential of 150 volts, and continuing over potential supply conductor 532, point 533, resistor 534 of 500 ohms, point 535, resistor 536 of 5,000 ohms, and point 537 to the anode 530. The screen grid 538 is given a normal positive potential of 150 volts by being connected to point 535 in the above anode circuit.

The control grid 527 is connected over point 539 and resistor 540 of 10,000 ohms to terminal 493, which, as explained before, is given a negative biasing potential of about 50 volts from one branch of the cathode potential supply circuit for the "I" routing control tube. The control grid 527 is also connected electrostatically to the common impulse conductor 360 from point 538 over a capacitor 541 of 100 micro-microfarads. The potential on the grid 527 is normally sufficiently negative that the tube 525 is not responsive to the positive potential impulses on the impulse conductor 360, but, when the "I" control tube of the routing control device is conducting, the potential rise of its cathode 470 will reduce the negative potential of grid 527, or "prime" the tube 525 so that it will be capable of responding to the impulses on conductor 360 and become conducting each time an impulse occurs on that conductor.

Whenever tube 525 becomes conducting, the potential of its anode 530 will drop due to the resistors 534 and 536 in its anode potential supply circuit, and, through an electrostatic connection from point 537 over capacitor 542 of 100 micro-microfarads and point 556, this drop is applied as a negative potential impulse on the control grid of the phase-changing and -amplifying tube 526.

Tube 526 is a zero-biased tube and is normally conducting. This tube has its cathode 544 directly connected to ground; its screen grid 545 connected over resistor 546 of 500 ohms, point 547, and conductor 548 to terminal 549, to which is applied a positive potential of 105 volts; and its control grid 555 connected to ground from point 556 over resistor 557 of 10,000 ohms, and also electrostatically connected to the anode 530 of tube 525, as explained above.

The anode 558 of the phase-changing and -amplifying tube 526 is connected over resistor 559 of 5,000 ohms to point 560 on the potential supply conductor 532, which is connected to terminal 531, to which is applied a positive potential of 150 volts. As this tube is normally conducting, anode 558 will normally have a potential of 50 volts, but, whenever a negative potential impulse is impressed on the control grid 555, conduction in the tube will be reduced and the potential of the anode will rise. A potential-tapping member 561 cooperates with resistor 559 to enable this rise to be utilized as a positive potential impulse which is impressed on the firing impulse conductor 423 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 561 to the firing impulse conductor extends from the potential-tapping member 561 over conductor 562 to terminal 425, which, as explained above, is connected to terminal 424 (Fig. 7), to which the firing impulse conductor 423 is connected.

The other relay means will, when effective, relay impulses from the common impulse conductor 360 to the firing impulse conductors of their respective banks.

Terminals 563, 564, 565, and 566 (Fig. 13), which are connected to terminals 567, 568, 569, and 570, respectively (Fig. 12), supply biasing potential to the various relay means and enable the "II," "III," "IV," and "V" control tubes of the routing control device to prime the relay means one after another.

As explained earlier herein, terminal 463 (Fig. 12) is connected to terminal 459 (Fig. 8), to which the firing impulse conductor 455 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 360.

Similarly, terminals 464, 465, and 466 (Fig. 12) are connected to terminals 460, 461, and 462 of Figs. 9, 10, and 11, respectively, to enable the third, fourth, and fifth bursts of impulses to be relayed to the firing conductors 456, 457, and 458 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 applicants' novel communication system, the symbols making up the data to be transmitted are set up on the plurality of banks of symbol-representing keys in the sending apparatus. These keys control banks of gaseous electron tubes to control the number of impulses that will be included in the various bursts which will be used to represent the symbols. A start key is depressed to start the automatic and sequential firing of the tubes in each of the banks in succession, and as the tubes in the banks are fired, they cause a signal-generating means to send out bursts of impulses, each burst containing a number of small-amplitude impulses and a large-amplitude, marking impulse. The bursts of impulses are sent out at a high rate of speed, 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 50 kilocycles and the time interval between bursts is about 100 microseconds.

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.

As the bursts of impulses are received by the receiving apparatus, the discriminating means passes them to the relay means for the various banks of transforming and symbol-storing tubes. The discriminating means also distinguishes between the small- and large-amplitude impulses of a burst and causes the routing control device to operate and prime the relay means for the next bank when the large-amplitude impulse is received, so that the next burst of impulses will be routed to the next bank of transforming and symbol-storing tubes. In this manner, the relay means are primed one after another as the bursts are received, and cause the various bursts to be relayed to the proper banks of transforming and symbol-storing tubes.

The impulses relayed to the various banks of transforming and symbol-storing tubes 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.

Applicants' novel communication system, therefore, transforms data into bursts of different numbers of rapidly recurring discrete signals and transmits the bursts of signals to a receiving apparatus where they are transformed back into representations of the data.

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.

The claims of this application are drawn to the communication system. A divisional application, Serial No. 523,024, filed February 19, 1944, contains claims to the sending apparatus per se, while another divisional application, Serial No. 523,025, filed February 19, 1944, contains claims to the receiving apparatus per se.

What is claimed is:

1. 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; electronic means at the sending station for generating signals at a supersonic frequency, while signals are generated in uniformly spaced bursts of different numbers of rapidly recurring signals according to symbols being transmitted; means to transmit the bursts of signals one after another over a single communication channel to the receiving station; and electronic means at the receiving station, responsive to signals having supersonic frequency, and controlled by the number of signals in the various bursts as they are received, to set up direct representations of the symbols to which the different numbers of signals have been assigned.

2. 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; presettable means at the sending station for setting up a plurality of symbols to be transmitted; means at the sending station controlled by the presettable means for generating uniformly spaced bursts of supersonic signals, each burst containing the required number of signals assigned to the particular symbol which it represents; means to transmit the bursts of signals one after another over a single communication channel to the receiving station; a plurality of means at the receiving station, each of said plurality of means being responsive to the supersonic signals in a different one of the bursts, and being differentially operated according to the number of signals to set up direct representations of the symbols to which the different numbers of signals in the bursts have been assigned; and means at the receiving station to receive the successive bursts of signals and route them to control different ones of the plurality of means.

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 controlled by the set-up means for automatically generating uniformly spaced bursts of different numbers of supersonic signals according to symbols being transmitted, each burst terminating with a distinctive marking signal; means to transmit the bursts of similar signals together with their related marking signals one after another over a single communication channel to the receiving station; a plurality of differentially operable electronic means at the receiving station, each differentially operable electronic means being responsive to the number of signals in a different one of the bursts, to transform the bursts of similar and marking signals into direct representations of the symbols to which the different numbers of signals have been assigned; and means in the receiving station responsive to the marking signals to cause the various ones of the differentially operable electronic means at the receiving station to be operated in sequence by the burst of signals to set up the direct representations of the symbols.

4. 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; means including electron tubes at the sending station for transforming the symbols one after another automatically into uniformly spaced bursts of different numbers of rapidly recurring signals according to symbols being transmitted; means to transmit the bursts of signals one after another over a single communication channel to the receiving station; a plurality of means at the receiving station, each means containing electron tubes and being differentially responsive to the number of 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; and routing means at the receiving station including electron tube switching means to enable the successive bursts of signals to control the various ones of the plurality of means in succession, said routing means being controlled by the last signal of a burst to 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.

5. 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; electron tube means at the sending station for generating bursts of different numbers of rapidly recurring signal impulses according to symbols being transmitted; a plurality of means successively operable to control the signal impulse generating means to govern the number of signal impulses that will be in each burst according to the symbols being transmitted; means to transmit the bursts of signal impulses, as they are formed, one after another over a single communication channel to the receiving station; a plurality of groups of electron discharge devices at the receiving station, each group being differentially responsive to the number of signal impulses in a different one of the bursts to set up

direct representations of the symbols to which the different numbers of signal impulses in the bursts have been assigned and routing means, upon which the groups of impulses are impressed at the receiving station, for routing the various bursts to their related group of electron discharge devices.

6. 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; electron tube means at the sending station for generating bursts of different numbers of rapidly recurring signal impulses according to symbols being transmitted; a plurality of groups of gaseous electron discharge tubes successively operable to control the signal impulse generating means to cause a signal impulse to be generated each time a tube is operated; means to select the number of tubes that will be operated in each of the plurality of groups to govern the number of signal impulses that will be in each burst according to the symbols being transmitted; means to transmit the bursts of signal impulses, as they are formed, one after another over a single communication channel to the receiving station; a plurality of groups of gaseous electron discharge tubes at the receiving station, each group of tubes being differentially responsive to the number of signal impulses in a different one of the bursts, and the different groups of tubes being controlled solely by the number of signal impulses to set up direct representations of the symbols to which the different numbers of signal impulses in the bursts have been assigned; and relay means upon which the impulses are impressed at the receiving station and which is selectively operable by the last signal impulse of a burst as the successive bursts are received to route the successive bursts of impulses to the different groups of gaseous electron discharge tubes at the receiving apparatus to enable the tubes of the groups to respond to the different numbers of signal impulses.

7. 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 a plurality of groups of manipulative devices at the sending station for setting up a pluraliy of symbols to be transmitted automatically one after another in succession; a plurality of groups of gaseous electron discharge tubes successively operable under control of said manipulative devices, which select the number of tubes to be operated, to transform the symbols being transmitted into their assigned number of signals; electronic means at the sending station for generating uniformly spaced bursts of different numbers of rapidly recurring signal impulses under control of said tubes according to the symbols being transmitted; means to transmit the bursts of signal impulses, as they are formed, one after another over a single communication channel to the receiving station; a plurality of groups of gaseous electron discharge tubes at the receiving station, each group of tubes being differentially responsive to the signal impulses in a different one of the bursts, and the different groups being controlled solely by the number of signal impulses to transform the signal impulses into direct representations of the symbols to which the different numbers of signal impulses in the bursts have been assigned; relay means upon which the bursts of impulses are impressed at the receiving station and which is selectively operable as the various bursts are received to route the bursts of signal impulses to the different groups of gaseous electron discharge tubes at the receiving station; and means, at the receiving station, controlled by the last impulse of each burst to cause the selective operation of the relay means to route the next burst to a different group of gaseous electron discharge tubes to enable the symbols which are transmitted to be transformed and set up in the receiving appaartus in the same order as in the sending apparatus.

8. A communication system in which different numbers of signals are assigned to represent different symbols which may be transmitted, which system comprises a sending station and a receiving station; means at the sending station for generating signals at supersonic frequency, which signals are generated in uniformly spaced bursts of different numbers of signals according to the symbols being transmitted; means to transmit the bursts of signals one after another, as they are generated, over a single communication channel to the receiving station; and means at the receiving station responsive to signals having supersonic frequency and controlled by the number of signals in the various bursts as they are received, to set up direct representations of the symbols to which the different numbers of signals have been assigned.

9. A communication system in which data is transmitted by signals having supersonic frequency and in which different numbers of signals are assigned to represent the various symbols making up the data which is to be transmitted, which system comprises a sending station and a receiving station; means at the sending station for setting up a plurality of symbols to be transmitted automatically one after another in succession; means at the sending station controlled by the set means to generate signals at supersonic frequency, which signals are generated automatically in a plurality of uniformly spaced bursts containing different numbers of signals according to various ones of the plurality of symbols being transmitted; means to transmit the bursts of signals, as they are generated, over a single communication channel to the receiving station; and means at the receiving station responsive to signals having supersonic frequency and controlled by the bursts of impulses as they are received for setting up direct representations of the symbols set on the means at the sending station.

10. A communication system in which each of the symbols making up data which may be transmitted is represented by a burst of impulses of supersonic frequency, said burst containing a preassigned number of similar impulses and a distinctive impulse, said system comprising 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 the presettable means according to the setting thereof for generating uniformly spaced bursts of impulses at a supersonic frequency, each burst containing the preassigned number of similar impulses according to the symbol being transmitted and terminating with the distinctive impulse; means to transmit the bursts of impulses from the sending station to the receiving station; a plurality of normally inoperable electronic means at the receiving station, each of said normally

inoperable electronic means, when operable, being differentially operable by the impulses of a burst, according to the number of impulses, to set up a direct representation of the symbol represented by the burst; and means at the receiving station preset to render one of the normally inoperable electronic means operable by the impulses of the first burst received, and controlled by the distinctive impulses to render different ones of the normally inoperable electronic means operable by the various succeeding bursts as they are received.

11. A communication system in which each of the symbols making up data which may be transmitted is represented by a burst of impulses containing a preassigned number of similar impulses and a distinctive impulse, and which comprises a sending station and a receiving station; means at the sending station to generate the similar impulses; means at the sending station to generate the distinctive impulse; presettable means at the sending station for setting up a plurality of symbols to be transmitted; control means including electron discharge devices at the sending station controlled by said presettable means according to the setting thereof, and operating to control the operation of the similar impulse generating means and the distinctive impulse generating means to transform the plurality of symbols automatically into uniformly spaced bursts of rapidly recurring impulses, each burst containing the preassigned number of similar impulses according to the symbol being transmitted and terminating with the distinctive impulse; means to transmit the bursts of impulses 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 electronic means being made up of electron discharge devices and being responsive quickly enough to be operated by the impulses of a burst generated under control of the control means at the sending station and operating to set up a direct representation of the symbol represented by the burst; and electronic switching means including electron discharge devices at the receiving station upon which the bursts of impulses are impressed and which is operable under the control of the distinctive impulses to selectively switch the bursts of impulses, as they are received, to the various ones of the plurality of differentially operable electronic means.

12. A communication system in which each of the symbols making up the data which may be transmitted is represented by a burst of impulses containing a preassigned number of small-amplitude impulses and a large-amplitude impulse and which comprises a sending station and a receiving station; electronic means at the sending station for generating the small-amplitude impulses; electronic means at the sending station for generating the large-amplitude impulses; manipulative means at the sending station for setting up a plurality of symbols to be transmitted; electronic means at the sending station, controlled by the manipulative means according to the setting thereof, and operating to control the operation of the small-amplitude-impulse generating means and the large-amplitude-impulse generating means to generate impulses at a supersonic frequency and produce uniformly spaced bursts of impulses, each burst containing the preassigned number of small-amplitude impulses according to the symbol being transmitted and terminating with the large-amplitude impulse; means to transmit the bursts of impulses one after another over a single communication channel from the sending station to the receiving station; a plurality of groups of electronic devices at the receiving station, the devices of each group being interconnected for sequential operation by the impulses of a burst to set up a direct representation of the symbol corresponding to the number of impulses in the burst; and electronic switching means at the receiving station which is preset to direct the first burst of impulses to one of the groups of electronic devices to cause their operation and which is operated by the large-amplitude impulse of each burst to switch the next burst of impulses to cause the operation of another of the groups of electronic devices.

13. 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; electron tube means at the sending station for generating uniformly spaced bursts of different numbers of rapidly recurring discrete signals according to symbols being transmitted; means to transmit the bursts of signals one after another over a single communication channel to the receiving station; a plurality of normally inoperative means at the receiving station, each of said normally inoperative means being made up of electron tubes and, when operative, being differentially responsive to and controlled solely by the number of signals in a different one of the various bursts to set up a direct representation of the symbol to which the number of signals in the burst has been assigned; and means for rendering different ones of said plurality of means operative as the different bursts are received, thereby to enable the plurality of means to set up direct representations of the symbols according to the numbers of signals in the various bursts.

JOSEPH R. DESCH.
ERNEST V. GULDEN.
ROBERT E. MUMMA.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,248,937	Bellamy	July 15, 1941
1,945,470	Steeneck	Jan. 30, 1934
2,103,296	Nelson	Dec. 28, 1937
2,192,217	Bellamy	Mar. 25, 1940
2,034,064	Steeneck	Mar. 17, 1936
2,096,954	Bellamy	Oct. 26, 1937
2,103,297	Nelson	Dec. 28, 1937
2,310,105	Michel	Feb. 2, 1943
853,888	Leake	May 14, 1907
1,313,816	Harris	Aug. 19, 1919
2,048,506	Husta	July 21, 1936
2,303,016	Blount	Nov. 24, 1942
1,709,031	McCoy	Apr. 16, 1929
2,373,134	Massonneau	Apr. 10, 1945

FOREIGN PATENTS

Number	Country	Date
209,023	Great Britain	Dec. 29, 1924

Certificate of Correction

Patent No. 2,425,307. August 12, 1947.

JOSEPH R. DESCH ET AL.

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows: Column 8, line 58, for "leters" read *letters*; column 11, line 21, before the word "grid" insert *control*; column 22, line 1, for "therein" read *thereon*; column 24, line 39, for "tubes" read *tube*; column 25, line 57, for the reference numeral "552" read *452*; column 31, line 35, claim 1, for "while" read *which*; 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 21st day of October, A. D. 1947.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.