Oct. 19, 1948. J. R. DESCH ET AL 2,451,812

ELECTRON TUBE VARIABLE IMPULSE TRANSMITTER

Original Filed Sept. 16, 1942 6 Sheets-Sheet 1

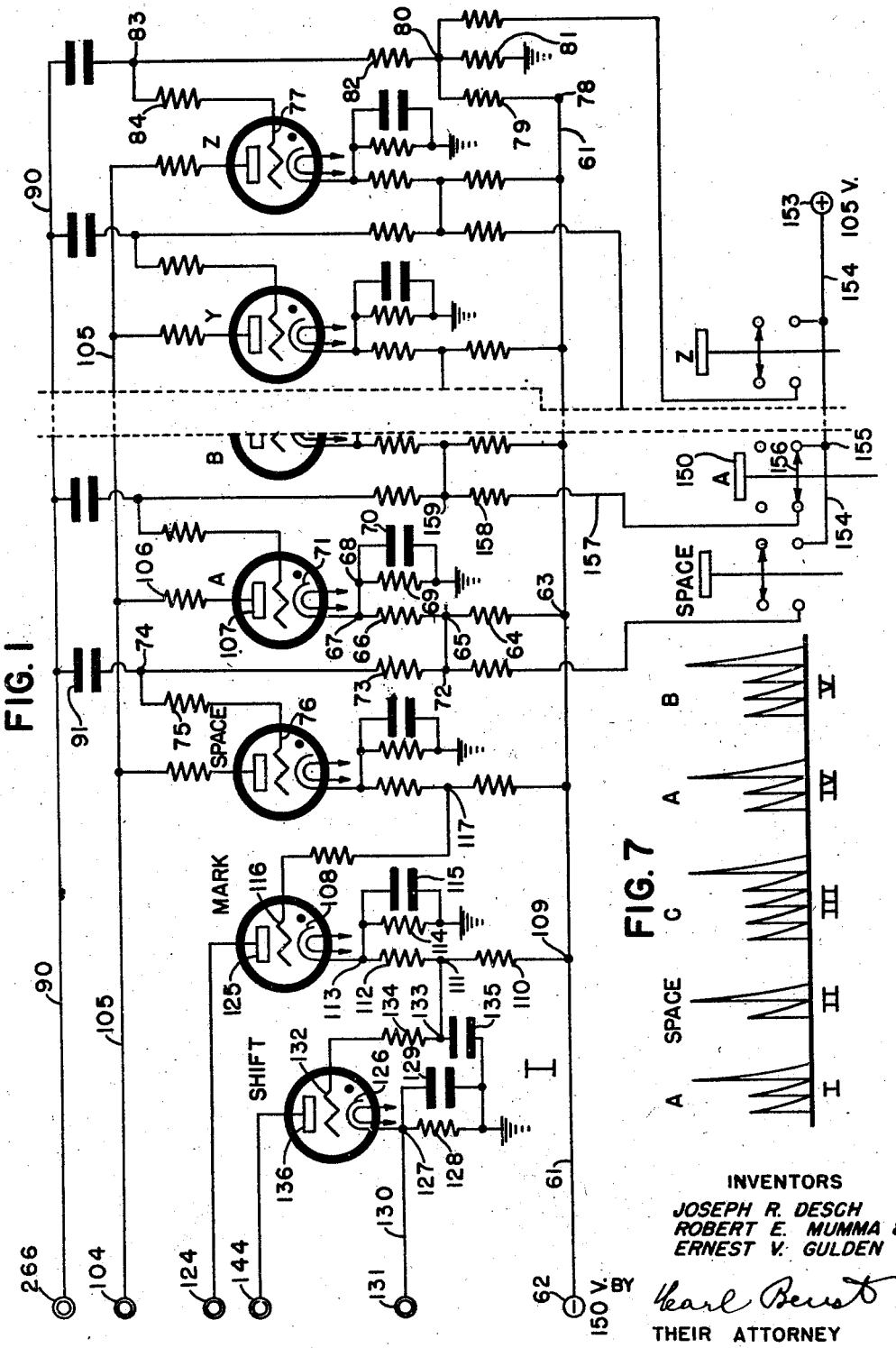


FIG. 1




FIG. 7

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ELECTRON TUBE VARIABLE IMPULSE TRANSMITTER

Original Filed Sept. 16, 1942 6 Sheets-Sheet 2

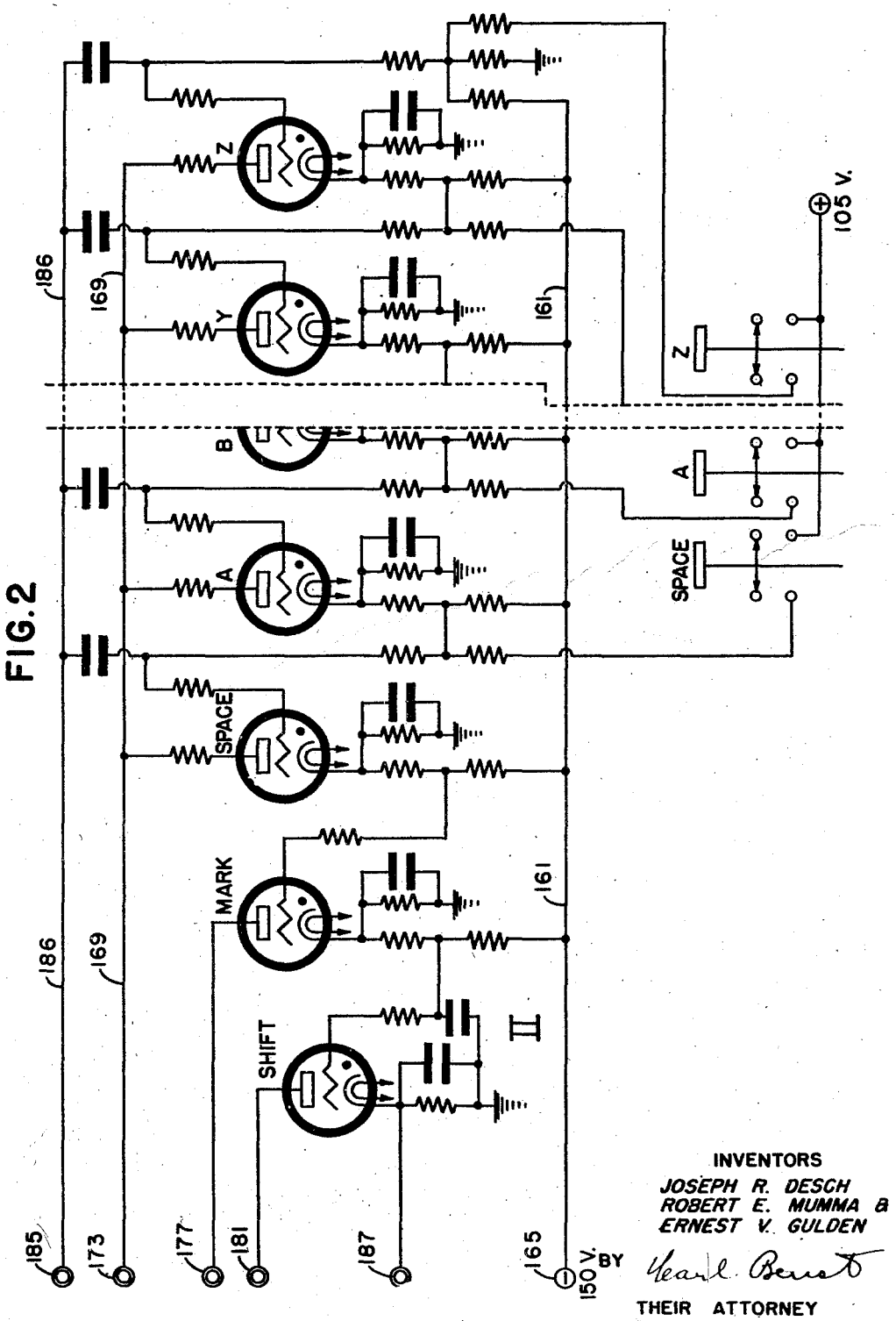


FIG. 2

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ELECTRON TUBE VARIABLE IMPULSE TRANSMITTER

Original Filed Sept. 16, 1942 6 Sheets-Sheet 3

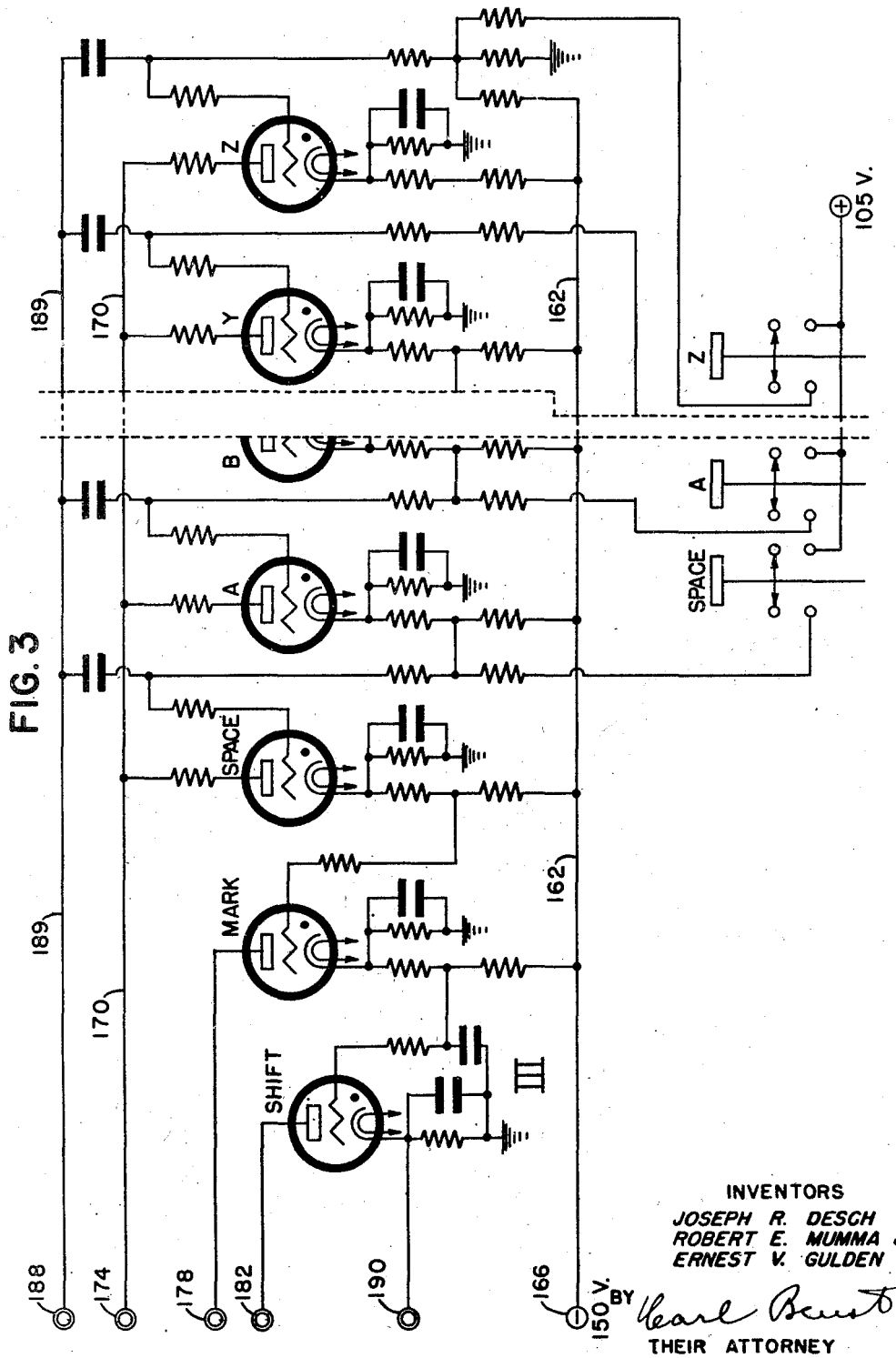


FIG. 3

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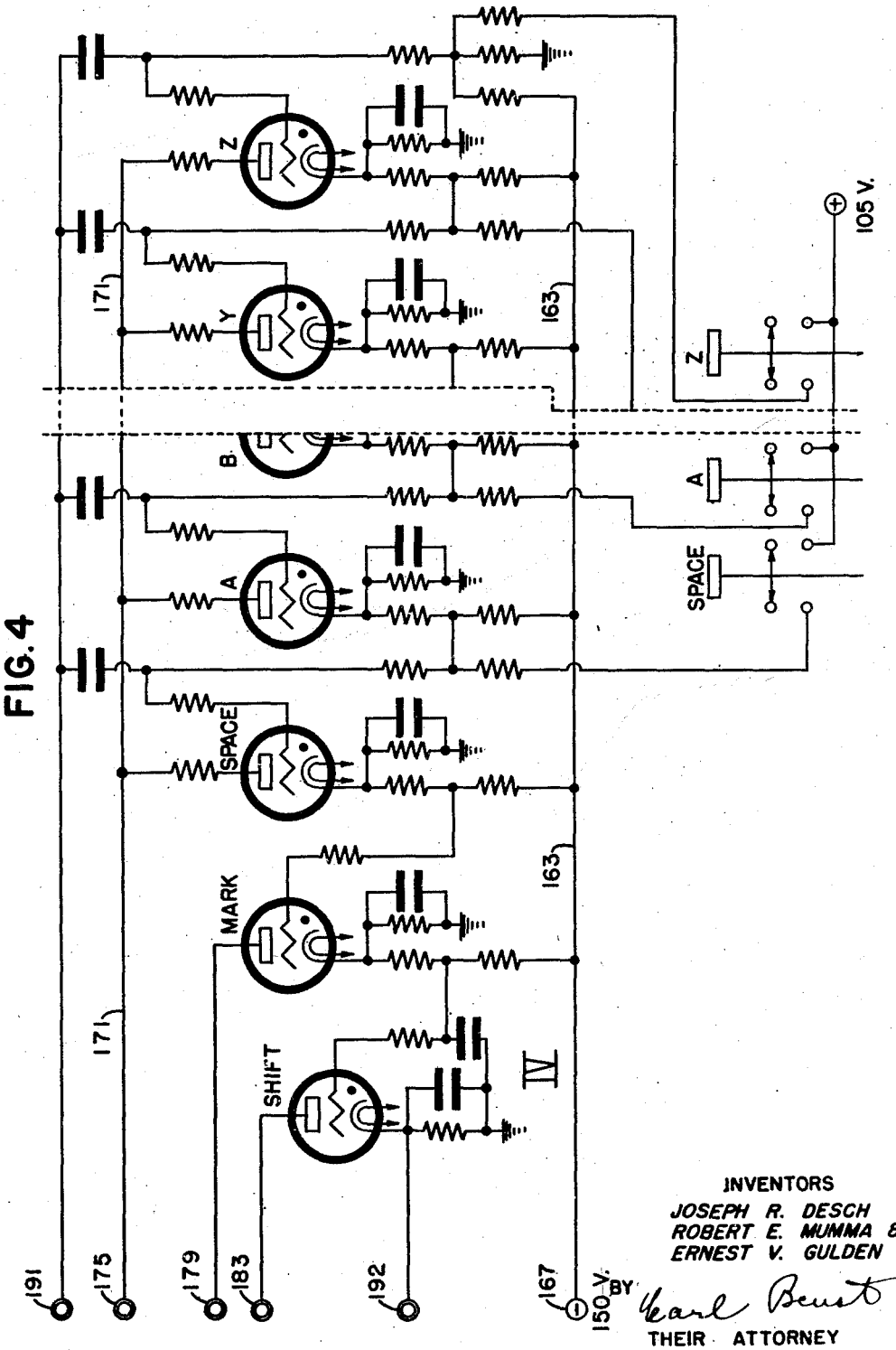
ELECTRON TUBE VARIABLE IMPULSE TRANSMITTER

Original Filed Sept. 16, 1942 6 Sheets-Sheet 4

FIG. 4

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ELECTRON TUBE VARIABLE IMPULSE TRANSMITTER

Original Filed Sept. 16, 1942 6 Sheets-Sheet 5

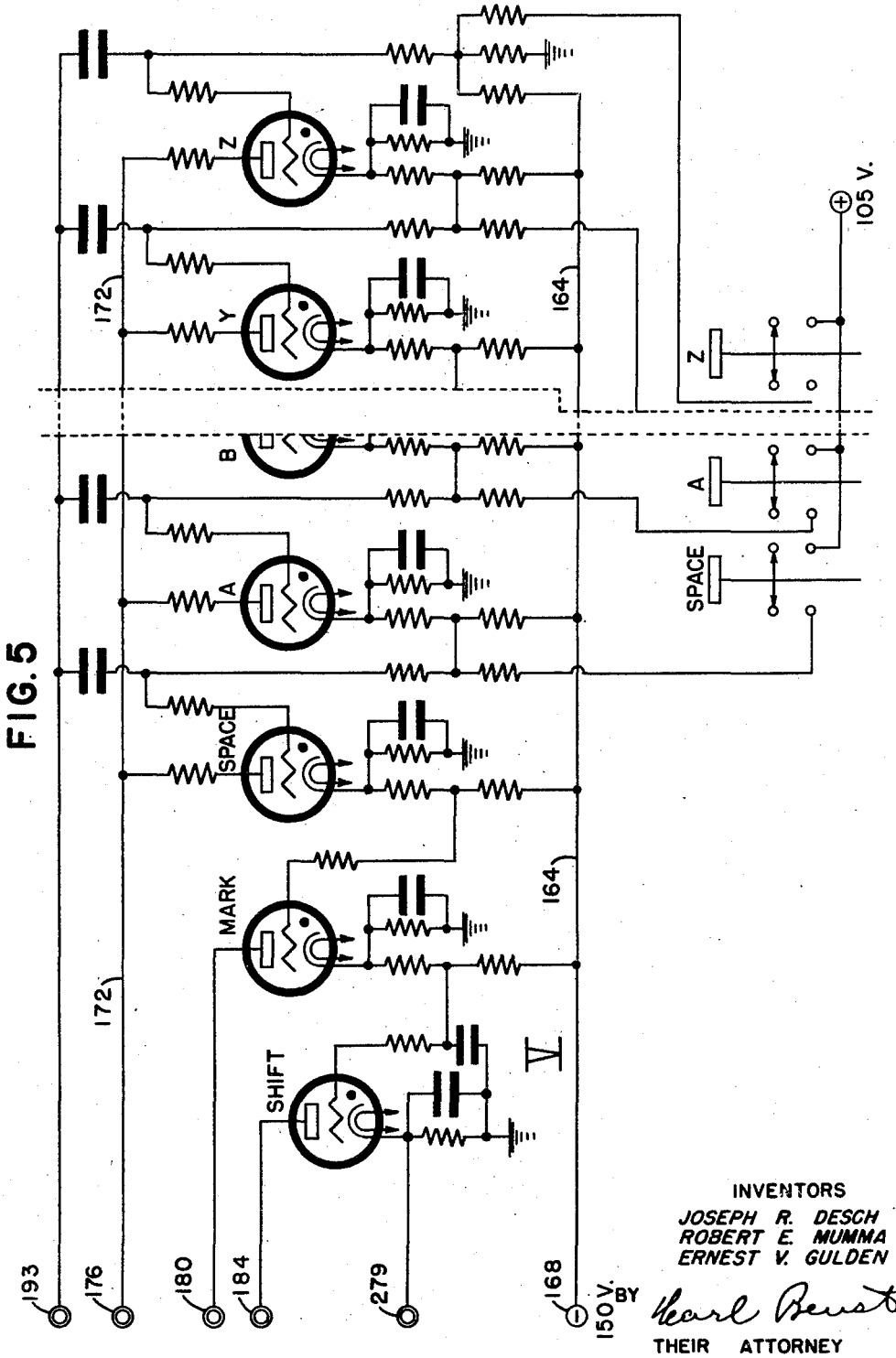


FIG. 5

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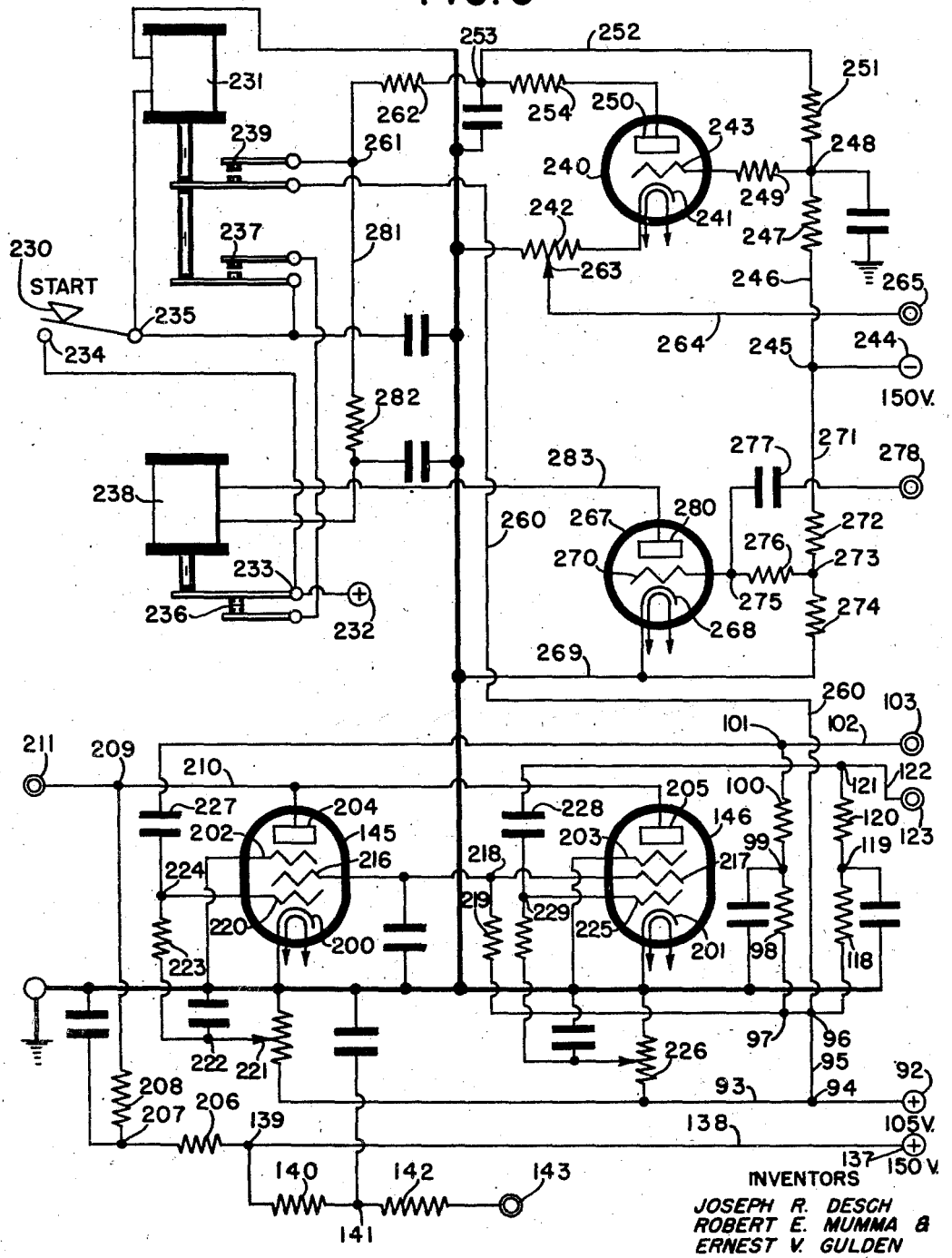
ELECTRON TUBE VARIABLE IMPULSE TRANSMITTER

Original Filed Sept. 16, 1942 6 Sheets-Sheet 6

FIG. 6

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Patented Oct. 19, 1948 2,451,812

# UNITED STATES PATENT OFFICE

2,451,812

## ELECTRON TUBE VARIABLE IMPULSE TRANSMITTER

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Original application September 16, 1942, Serial No. 458,546, now Patent No. 2,425,307, dated August 12, 1947. Divided and this application February 19, 1944, Serial No. 523,024

24 Claims. (Cl. 177—380)

1

This invention relates to communication systems and is directed particularly to a sending apparatus or signal generating means for use in a system in which various symbols making up the data to be transmitted are transformed into spaced bursts or trains of discrete rapidly recurring signals, the number of signals in each burst being dependent upon the symbol which is represents. The bursts representing the different symbols are sent one after another over a single communication channel with suitable spacing between bursts, 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.

This application is a division of the application for United States Letters Patent, Serial No. 458,546, which was filed by Joseph R. Desch, Ernest V. Gulden, and Robert E. Mumma on September 16, 1942, now U. S. Letters Patent 2,425,307, granted Aug. 12, 1947.

The sending apparatus is provided with means for generating the spaced 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.

High-speed communication of data is obtained with applicants' novel arrangement because the sending apparatus can generate 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 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.

With these and incidental objects in view, the invention includes certan 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.

Fig. 7 is a representation of five bursts which

may be generated 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 of the invention 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 or impulse generating means 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 be 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 after a suitable time, 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 the 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 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 signals or impulses which could control a receiving apparatus in the same manner as though the signals were generated by the five banks automatically in the five-symbol sequence explained above.

Thus it is seen that applicants have provided a novel sending apparatus or signal generating means which can operate at a high rate of speed to generate different numbers of signals which represent symbols of data to be transmitted.

## Detailed Description

The disclosed embodiment of the invention is adapted to send five symbols automatically in succession in the form of bursts of impulses. Fig. 7 shows, in a general way, a representation of a train of impulses made up of the bursts of impulses which would be generated to represent 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 have been applied to the parts of the sending 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 accordingly to maintain the proper relation between the various parts of the circuit. Throughout the drawings the cathode heater elements are shown conventionally.

Referring to Fig. 1, which shows a symbol-transforming means for the first symbol to be transmitted, it will be seen that the symbol-transforming means is made up of a plurality of gaseous electron tubes. 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 letters "C" to "X" inclusive having been omitted to simplify the showing of the bank because the circuits for these tubes are identical with those of other symbol-representing 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 inter-connecting 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 cathode potential 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 control 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 microfarad 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 "mark" 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 "mark" 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 (Fig. 1) of the shift tube "shift" 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 shift 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 conducting. 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 a 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 (Fig. 6) 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 (Fig. 1) 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 188, terminal 184, and terminal 183 (Fig. 6) 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 (Fig. 1) 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 (Fig. 6) 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 included 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 (Fig. 1) 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 (Fig. 6). 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 (Fig. 1) 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 (Fig. 6) 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 (Fig. 1), 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-transformed 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 181, 182, 183, and 184 for the banks "II," "III," "IV," and "V," (Figs. 2, 3, 4 and 5) is connected, respectively, to a terminal, as 185, 186, 187, and 188, upon which is impressed a negative potential of 150 volts.

The symbol-representing control tube anode potential supply conductors 168, 170, 171, and 172 for banks "II," "III," "IV," and "V" (Figs. 2, 3, 4, and 5) 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 (Figs. 2, 3, 4 and 5) 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 the anode of any marking impulse tube 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, (Fig. 1) as the shift tube is fired, can be impressed on the starting impulse conductor 186 (Fig. 2) 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 (Fig. 2), 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 com-

pleted 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-microfarads 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 208 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.

## Operation

In the operation of applicants' novel sending apparatus or signal generating means, 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 spaced bursts of impulses, each burst containing a number of small-amplitude impulses as controlled by the bank of keys related to the bank of tubes, and also containing 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 frequency rate of about 50 kilocycles, and the time interval between bursts is about 100 micro-seconds.

While the form of apparatus 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 shown herein, for it is susceptible of embodiment in various forms all coming within the scope of the claims which follow.

What is claimed is:

1. In an electric impulse generator, the combination of electron discharge tube means selectively operable to produce small-amplitude and large-amplitude rapidly recurring discrete positive impulses; and selectively operable means to control the selective operation of the electron discharge tube means to produce an impulse train containing a plurality of groups of selected numbers of small-amplitude impulses separated by large-amplitude impulses.

2. In a communication system in which different numbers of signals are assigned to represent different symbols which may be transmitted, the combination of a first electronic means variously operable to generate different numbers of similar signals and further electronic means to generate a distinctive control signal; manipulative means selectively operable according to the particular symbol to be transmitted; means connecting the manipulative means to said first electronic means to enable the manipulative means to selectively control said first electronic means according to the symbol being transmitted to govern the number of similar signals which will be generated; and means controlled by said connecting means and operable to cause said further electronic means to generate before the distinctive control signal following the desired numbers of similar signals.

3. In a communication system in which different numbers of signals are assigned to represent the different symbols which may be transmitted, the combination of electronic means for generating spaced groups of supersonic signals, each group containing a desired number of similar rapidly recurring signals followed by a distinctive control signal, said electronic means including a first electron tube means for generating the similar signals and a further electron tube means for generating the distinctive control signal; manipulative means selectively operable according to the particular symbols to be transmitted; means connecting the manipulative means to said first electron tube means to enable the manipulative means to selectively control said first electron tube means to control the various numbers of similar signals which will be generated before the distinctive control signal in the various groups of signals; and means controlled by said connecting means and operable to cause said further electron tube means to generate the distinctive control signal after the last similar signal of the group.

4. In an apparatus of the class described, the combination of a bank of electron devices; means connecting the electron devices in a chain sequence, the connections between adjacent electron devices of the chain sequence enabling conduction in one device to cause the next device of the sequence to operate automatically and become conducting so that the electron devices will operate and become conducting automatically one after another in sequence toward one end of the chain after any electron device in the chain has been rendered conducting to initiate the sequential operation of the electron devices in the bank; means to select any one of the electron devices with which the sequential operation is to begin to thereby select the number of electron devices which will operate; and means to cause the selected electron device to become conducting and initiate the automatic sequential operation of the electron devices from the selected electron device toward said one end of the chain of electron devices.

5. In an apparatus of the class described, the combination of a bank of gaseous electron discharge tubes, each tube containing an electrode pair and a means to control conduction therein; means connecting the electron tubes in a chain sequence, the connection between adjacent tubes of the chain sequence including one of the pair of electrodes in the prior tube in the sequence and the control means of the next tube in the sequence so that, when any tube of the sequence is fired and becomes conducting, it will cause the next tube in the sequence automatically to become conducting, thus enabling the tubes to be fired and become conducting automatically one after another in sequence toward one end of the chain after any electron tube in the bank has been fired and rendered conducting; means to vary the control by the control means in the tubes to select any one of the electron tubes with which the sequential operation is to begin, so that the firing of the tubes may begin at any point in the chain, thus enabling different numbers of tubes in the bank to be selected for sequential operation; and means to modify the control by the control means in the tubes further to cause the selected electron tube to be fired and become conducting to initiate the automatic sequential firing of the selected number of electron tubes which follow the selected tube in the chain sequence.

6. In an apparatus of the class described, the combination of a bank of gaseous electron tubes; means connecting the electron tubes in a chain sequence, the connection between adjacent tubes of the chain sequence including one of the pair of electrodes in the prior tube in the sequence and the control means of the next tube in the sequence so that, when any tube of the sequence if fired and becomes conducting, it will cause the next tube in the sequence automatically to become conducting, thus enabling the tubes to be fired and become conducting automatically one after another in sequence at supersonic frequency toward one end of the chain after any electron tube in the bank has been fired and rendered conducting; manipulative means to modify the control by the control means in the tubes to select any one of the electron tubes with which the sequential operation is to begin, so that the firing of the tubes may begin at any point in the chain, thus enabling different numbers of tubes in the bank to be selected for sequential operation; means to modify the control by the control means in the tubes further to cause the selected electron tube to be fired and become conducting to initiate the automatic sequential firing of the selected number of electron tubes which follow the selected tube in the chain sequence; and signal generating means controlled by the tubes in the bank as they are fired in succession to create a burst of signals having supersonic frequency and containing a number of signals as determined by the selected point in the bank at which the sequential firing of the tubes began.

7. In a device of the class described, the combination of a plurality of gaseous electron tubes, each tube containing an anode, a cathode, and a control grid; means to supply positive potential to the anodes of the tubes; separate negative potential supply means for the cathode of each tube, said separate supply means including resistors to cause the potential of the cathode of a tube to rise when that tube

ing; means for supplying negative potential bias to the control grids for connecting the tubes for automatic operation one after another in sequence, said last-mentioned means consisting of circuits extending from the cathode potential supply means for any of the various tubes to the control grid of the next tube to be operated in the sequence, said circuits supplying normal negative bias to the control grids and enabling the potential rise of the cathode of a tube in the sequence to reduce the bias of the control grid of the next tube in the sequence to cause the automatic sequential firing of the tubes after any tube has been fired and rendered conducting; means to impress a starting impulse on the control grids of the tubes, said starting impulse being ineffective to overcome the normal negative bias on the control grids; and means to select with which tube in the sequence the sequential firing will begin, said means being effective to reduce the negative bias on the control grid of the selected tube so that the starting impulse can fire that tube and initiate the automatic sequential firing of the tubes succeeding the selected tube in the sequence.

8. In an apparatus of the class described, the combination of a plurality of banks of electron devices; means connecting the electron devices of each bank in an operating chain sequence, the connections enabling a device, when operated, to cause the next device of the sequence to operate so that the devices of a bank will operate and become conducting automatically one after the other in sequence after any electron device of the bank has been operated; a plurality of banks of manipulative devices, one bank related to each bank of electron devices; means controlled by the manipulative devices for selecting the electron device in each bank with which the sequential operation is to begin; means to cause the selected electron device in the first bank to be operated, to operate and initiate the automatic operation of the electron devices succeeding the selected electron device in the sequence in that bank; and means to connect the banks of electron devices for sequential operation, including a connection from the last electron device in the sequence in one bank to the electron devices of the next bank to be operated, whereby the operation of the last electron device in the sequence in one bank will cause the selected electron device in the next bank to be operated and initiate the automatic operation of the electron devices in the next bank.

9. In an apparatus of the class described, the combination of a plurality of banks of electron devices; means connecting the electron devices of each bank in a chain sequence, the connections enabling a device, when operated, to cause the next device of the sequence to operate, so that the devices of a bank will operate and become conducting automatically one after the other in sequence toward one end of the chain after any electron device of the bank has been operated to initiate the sequential operation of the electron devices of the bank; a plurality of banks of manipulative devices, one bank related to each bank of electron devices; means controlled by the manipulative devices for selecting the electron device in each bank with which the sequential operation is to begin; means to connect the banks of electron devices for sequential operation, including a connection from the last electron device of the chain sequence in one bank to the electron devices of the next bank to be operated, whereby the operation of the last electron device in the chain sequence in one bank will cause the selected electron device in the next bank to operate and initiate the automatic operation of the electron devices in the next bank; operation-initiating means to cause the selected electron device in the first bank to be operated, to operate and initiate the automatic operation of the electron devices succeeding the selected electron device in the chain sequence in that bank and, through the connection between successive banks, to enable the sequential operation of the electron devices in the various banks in succession; and means operated by the last device in in the chain sequence in the last bank to restore the operation-initiating means for further operation.

10. In an apparatus of the class described, the combination of a plurality of banks of gaseous electron tubes; means connecting the electron tubes of each bank in a chain sequence so that they will be fired and become conducting automatically one after the other in sequence toward one end of the chain after any electron tube of the bank has been fired; a plurality of banks of manipulative devices, one bank related to each bank of electron tubes; circuits selectively closable by the manipulative devices for selecting the electron tube in each bank with which the sequential firing is to begin; means to cause the selected electron tube in the first bank to be operated, to be fired and initiate the automatic firing of the electron tubes succeeding the selected electron tube in the chain sequence in that bank; means to connect the banks of electron tubes for sequential operation, including a connection from the last electron tube in one bank to the electron tubes of the next bank to be operated, whereby the firing of the last electron tube in the sequence in one bank will cause the selected electron tube in the next bank to be fired and initiate the automatic firing of the electron tubes in the next bank; and means to delay the operation of the last tube in the chain sequence in each bank to delay the initiation of the firing of the tubes in the next bank, thereby to provide a time interval between the operation of the different banks of tubes.

11. In an apparatus of the class described, the combination of a plurality of banks of gaseous electron tubes; means connecting the electron tubes of each bank in a chain sequence, said connections enabling conduction in one tube to cause the next tube to be fired so that the tubes will be fired and become conducting automatically one after the other in sequence toward one end of the chain after any electron tube of the bank has been fired to initiate the sequential firing of the electron tubes of the bank; a plurality of banks of manipulative devices, one bank related to each bank of electron tubes; means controlled by the manipulative devices for selecting the electron tube in each bank with which the sequential firing is to begin to thereby select the number of tubes in each bank which will be fired; means to cause the selected electron tube in the first bank to be operated, to be fired and initiate the automatic firing of the electron tubes succeeding the selected electron tube in the sequence in that bank; means to connect the banks of electron tubes for sequential operation, including a connection from the last electron tube in a bank to the electron tubes of the next bank to be operated, whereby the firing of the last electron tube in the sequence in one bank will cause the se-

lected electron tube in the next bank to fire and initiate the automatic firing of the electron tubes in the next bank, thus enabling the sequential firing of the electron tubes in the various banks to take place in automatic succession after the selected tube in the first bank has been operated; and signal-generating means controlled by the tubes in the several banks to create a burst of signals for each bank, each burst containing a number of signals as determined by the number of tubes selected in the various banks by the manipulative devices.

12. In a device of the class described, the combination of a plurality of groups of gaseous electron tubes; means connecting the tubes of each group so that they will be fired and rendered conducting one after another in sequence; means connecting the groups so that the sequential firing of the tubes in the groups will take place in one group after another in sequence; means connected to all the tubes to produce an impulse each time any of the tubes in any group is fired and becomes conducting; and signal-generating means controlled by the means connected to all the tubes and operable to generate a signal each time an impulse is produced by the firing of a tube in any group.

13. In a device of the class described, the combination of a plurality of groups of gaseous electron tubes; means connecting the tubes of each group so that they will be fired and rendered conducting one after another in sequence, said connections enabling a tube, when rendered conducting, to automatically cause the next tube in the sequence to be fired; time delay means connecting the groups so that the sequential firing of the tubes in the groups will take place in one group after another in sequence with a time delay between the firing of the tubes in the different groups; means connected to all the tubes to produce groups of control impulses as the tubes in the various groups are fired and become conducting; and signal-generating means controlled by said tubes, through the means connected to all the tubes, to produce bursts of similar signal impulses as the groups of control impulses are produced by the firing of the gaseous electron tubes.

14. In a device of the class described, the combination of a plurality of groups of gaseous electron tubes, each tube having an anode, a cathode, and a control grid; means to supply negative potential to the cathode of each tube; cathode-control grid circuits for connecting the tubes in the groups so that the tubes in each group will be fired and rendered conducting one after another in sequence; means connecting the groups of tubes to cause the sequential firing of the tubes to take place in the different groups one group after another; means connecting the anodes of all the tubes in all the groups together and over a common resistor to a source of positive potential to enable the firing of any tube in any group to cause a drop in the potential on the anodes of all the tubes; and signal-generating means connected to the means connecting the anodes together and controlled by the potential drop as each tube is fired, for generating a signal impulse each time a tube in any group is fired.

15. In a device of the class described, the combination of a plurality of groups of gaseous electron tubes, each tube having an anode, a cathode, and a control grid; means to supply negative potential to the cathode of each tube; cathode-control grid circuits for connecting the tubes in the groups so that the tubes in each group will be



fired and rendered conducting one after another in sequence; means, including time delay means, for connecting the groups of tubes to cause the sequential firing of the tubes to take place in the different groups one group after another with a time delay between the firing of the tubes in the various groups; means connecting the anodes of all the tubes in all the groups together and over a common resistor to a source of positive potential to enable the firing of any tube in any group to cause a drop in the potential on the anodes of all the tubes; and signal-generating means controlled by the tubes to produce a burst of signal impulses for each group, said signal-generating means including a vacuum tube having a control grid connected to the means connecting the anodes, thus enabling the drop in potential as any tube is fired to control the vacuum tube to produce a signal impulse.

16. In a device of the class described, the combination of a plurality of groups of gaseous electron tubes; means connecting the tubes of each group so that they will be fired and rendered conducting one after another in sequence; manipulative means to differentially control the number of tubes that will be fired in sequence in each group; means connecting the groups so that the sequential firing of the tubes in the groups will take place in one group after another in sequence; means connected to all the tubes to produce an impulse each time any of the tubes in any group is fired and becomes conducting; and signal-generating means controlled by the means connected to all the tubes and operable to generate a signal each time an impulse is produced by the firing of a tube in any group under control of the manipulative means.

17. In a device of the class described, the combination of a plurality of groups of gaseous electron tubes; means connecting the tubes of each group so that they will be fired and rendered conducting one after another in sequence, the connections enabling a tube of a group, when rendered conducting, to cause the next tube in the sequence to be fired; manipulative means to select with which tube in each bank the sequential operation will begin, thereby to differentially control the number of tubes that will be fired in sequence in each group; means, including time delay means, for connecting the groups so that the sequential firing of the tubes in the groups will take place in one group after another in sequence with a time delay between the firing of the tubes in the various groups; means connected to all the tubes to produce an impulse each time any of the tubes in any group is fired and becomes conducting; and signal-generating means controlled by the means connected to all the tubes and operable to generate a signal each time an impulse is produced by the firing of a tube in any group, whereby to produce spaced bursts containing different numbers of signals as controlled by the manipulative means.

18. In a device of the class described, the combination of a plurality of groups of gaseous electron tubes, each having at least an electrode pair and a control means; means connecting the tubes of each group so that they will be fired and rendered conducting rapidly one after another automatically in sequence, the connection between adjacent tubes of the sequence extending from an electrode of the electrode pair of one tube to the control means of the next tube in the sequence and enabling conduction in said one tube to cause said next tube to be fired automatically; a plural-

ity of banks of manipulative devices, one bank for each group of tubes, for selectively modifying the control exerted by the control means in the tubes to select with which tube of the group the automatic operation of the tubes of that group will begin, thereby differentially selecting the number of tubes of the groups that will be fired in sequence; means, including time delay means, for connecting the groups so that the sequential firing of the tubes in the groups will take place in one group after another in sequence with an interval between the firing of the tubes in the various groups; means connected to similar electrodes in all the tubes to produce an impulse each time any of the tubes in any group is fired and becomes conducting; and signal-generating means including a vacuum tube controlled by the means connected to similar electrodes in all the tubes and operable to generate a signal impulse each time an impulse is produced by the firing of a tube in any group, thereby to produce spaced bursts of different numbers of rapidly recurring signal impulses containing different numbers of signal impulses as determined by the selection made by the manipulative devices.

19. In a device of the class described, the combination of a plurality of groups of gaseous electron tubes; means connecting the tubes of each group so that they will be fired and rendered conducting one after another in sequence; means connecting the groups so that the sequential firing of the tubes in the groups will take place in one group after another in sequence; and means connecting the tubes of all the groups together so that the firing of any tube in any group will cause any previously conducting tube in any group to be extinguished, whereby the first tube to be fired in a succeeding group will extinguish the last tube which was fired and remained conducting in the preceding group.

20. In a device of the class described, the combination of a plurality of groups of gaseous electron tubes, each tube including at least an electrode pair and a control means; means connecting the tubes of each group so that they will be fired and rendered conducting one after another in sequence, the connection between adjacent tubes of the sequence extending from one of the electrodes of the electrode pair in one tube, to the control means of the next tube in the sequence; means connecting the groups so that the sequential firing of the tubes in the groups will take place in one group after another in sequence; and means including connections between similar ones of the electrodes of the electrode pairs in all of the tubes to produce an impulse each time any of the tubes in any group is fired and becomes conducting, each of said impulses being effective to cause any previously conducting tube in any group to be extinguished.

21. In a device of the class described, the combination of a plurality of groups of gaseous electron tubes, each tube having an anode, a cathode, and a control grid; means to supply negative potential to the cathode of each tube; cathode-control grid circuits for connecting the tubes in the groups so that the tubes in each group will be fired and rendered conducting one after another in sequence; means connecting the groups of tubes to cause the sequential firing of the tubes to take place in the different groups one group after another; and means connecting the anodes of all the tubes in all the groups together and over a common resistor to a source



of positive potential to enable the firing of any tube in any group to cause a drop in the potential on the anodes of all the tubes, which potential drop is effective to extinguish any previously conducting tube in any group, whereby the first tube to be fired in a succeeding group will extinguish the last tube which was fired and remained conducting in the preceding group.

22. In a sending apparatus for a communication system in which different numbers of signals are assigned to represent different symbols which may be transmitted, the combination of a plurality of gaseous electron tubes, certain of said tubes being symbol-representing control tubes and another of said tubes being a marking signal control tube, each of said tubes containing an anode, a cathode, and a control grid; means connecting the anodes of the symbol-representing control tubes over a common resistor to a source of positive potential so that a negative impulse will be produced each time one of these tubes is fired and becomes conducting; means connecting the anode of the marking signal control tube over a resistor to a source of positive potential to produce a negative impulse when the marking signal control tube is fired and becomes conducting; separate negative potential supply means for the cathode of each tube, said separate supply means including resistors to cause the potential of the cathode of any tube to rise when that tube becomes conducting; means for supplying negative potential bias to the control grids and for connecting the tubes for automatic operation one after another in a sequence beginning with the symbol-representing control tubes and ending with the marking signal control tube, said bias-supplying means consisting of circuits extending between successively operated tubes of the sequence and connecting the cathode potential supply means for any tube in the sequence to the control grid of the next tube to be operated in the sequence; said circuits supplying normal negative biasing potential to the control grids and enabling the potential rise of the cathode of a tube in the sequence to reduce the bias of the control grid of the next tube in the sequence to cause the automatic sequential firing of the tubes in the sequence after any tube in the sequence has been fired and rendered conducting; means to impress a starting impulse on the control grids of the symbol-representing control tubes, said starting impulse being ineffective to overcome the normal negative bias on these control grids; means to select with which symbol-representing control tube in the sequence the sequential firing will begin according to the symbol to be transmitted, said means operating to reduce the bias on the control grid of the selected tube so that the starting impulse can fire that tube and initiate the automatic sequential firing of the tubes succeeding the selected tube in the sequence; and means differentially controlled by the negative impulses in the several anode potential supply means to create a signal each time a symbol-representing control tube is fired and to create a distinctive marking signal when the marking signal control tube is fired, whereby a group of signals is formed to represent a symbol, which group of signals contains a number of similar signals followed by a distinctive marking signal.

23. In a sending apparatus for a communication system in which different numbers of signals are assigned to represent different symbols which may be transmitted, the combination of a

plurality of gaseous electron tubes, certain of said tubes being symbol-representing control tubes and another of said tubes being a marking signal control tube, each of said tubes containing an anode, a cathode, and a control grid; means connecting the anodes of the symbol-representing control tubes over a common resistor to a source of positive potential so that a negative impulse will be produced each time one of these tubes is fired and becomes conducting; means connecting the anode of the marking signal control tube over a resistor to a source of positive potential to produce a negative impulse when the marking signal control tube is fired and becomes conducting; separate negative potential supply means for the cathode of each tube, said separate supply means including resistors to cause the potential of the cathode of any tube to rise when that tube becomes conducting; means for supplying negative potential bias to the control grids and for connecting the tubes for automatic operation one after another in a sequence beginning with the symbol-representing control tubes and ending with the marking signal control tube, said bias-supplying means consisting of circuits extending between successively operated tubes of the sequence and connecting the cathode potential supply means for any tube in the sequence to the control grid of the next tube to be operated in the sequence, said circuits supplying normal negative biasing potential to the control grids and enabling the potential rise of the cathode of a tube in the sequence to reduce the bias of the control grid of the next tube in the sequence to cause the automatic sequential firing of the tubes in the sequence after any tube in the sequence has been fired and rendered conducting; means to impress a starting impulse on the control grids of the symbol-representing control tubes, said starting impulse being ineffective to overcome the normal negative bias on these control grids; means to select with which symbol-representing control tube in the sequence the sequential firing will begin according to the symbol to be transmitted, said means operating to reduce the bias on the control grid of the selected tube so that the starting impulse can fire that tube and initiate the automatic sequential firing of the tubes succeeding the selected tube in the sequence; a small-amplitude positive impulse generating tube; means enabling the negative impulses in the symbol-representing control tube anode potential supply means to cause the small-amplitude impulse generating tube to operate and provide a small-amplitude positive impulse each time a symbol-representing control tube is fired and becomes conducting; a large-amplitude positive impulse generating tube; and means enabling the negative impulse in the marking signal control tube anode potential supply means to cause the large-amplitude impulse generating tube to operate and provide a large-amplitude positive impulse when the marking signal control tube is fired, whereby a burst of impulses is formed to represent a symbol, said burst containing a group of small-amplitude impulses followed by a large-amplitude impulse.

24. In a sending apparatus for a communication system in which different numbers of signals are assigned to represent different symbols which may be transmitted, the combination of a plurality of banks of gaseous electron tubes, each bank containing a plurality of symbol-representing control tubes, a marking signal control tube, and a shift tube, and each of said tubes



containing an anode, a cathode, and a control grid; means connecting the anodes of the symbol-representing control tubes in the several banks over a common resistor to a source of positive potential so that a negative impulse will be produced each time one of the symbol-representing control tubes is fired and rendered conducting, said negative impulses being effective to extinguish any previously conducting symbol-representing control tube; means connecting the anodes of the marking signal control tubes of the various banks over a common resistor to a source of positive potential so that a negative impulse will be produced each time one of these tubes is fired and rendered conducting, said negative impulses being effective to extinguish any previously conducting marking impulse tube; means connecting the anodes of the shift tubes in the various banks over a common resistor to a source of positive potential so that a negative impulse will be produced each time a shift tube in any bank is fired and rendered conducting, said negative impulses being effective to extinguish any previously conducting shift tube; separate negative potential supply means for the cathode of each tube; cathode-control grid circuits between the tubes of each bank for connecting the tubes in a bank for automatic sequential operation beginning with any selected symbol-representing control tube, continuing through the marking signal control tube, and ending with the shift tube; means associated with each bank to impress a starting impulse on the control grids of the symbol-representing control tubes of that bank, said starting impulses being ineffective to fire these tubes unless the tubes have been prepared; means connecting the banks of tubes for sequential operation, comprising a circuit from the cathode of the shift tube of one bank to the starting means of another bank so that the firing of the shift tube in a bank can cause a starting impulse to be sent to the next bank in the sequence to initiate the sequential firing of the tubes therein; a plurality of banks of manipulative devices; means controlled by the manipulative device to selectively prepare the control grids of symbol-representing control tubes in the various banks to select with which tube in the several banks the sequential operation will begin; transmission-initiating means to supply a starting impulse to the first bank in the sequence, to start the sequential firing of the tubes in that bank; said connections between banks initiating the sequential firing of the tubes in the various banks, one bank after another in succession; a signal-generating means controlled by the anode potential supply means for the symbol-representing control tubes to generate a signal each time a negative impulse occurs in this supply means; and a marking signal generating means controlled by the anode potential supply means for the marking signal control tubes to generate a distinctive marking signal each time a negative impulse occurs in this supply means, said banks of tubes automatically in succession controlling the signal-generating means to create bursts of signals, each burst containing a number of similar signals followed by a distinctive marking signal.

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