

Nov. 19, 1935.

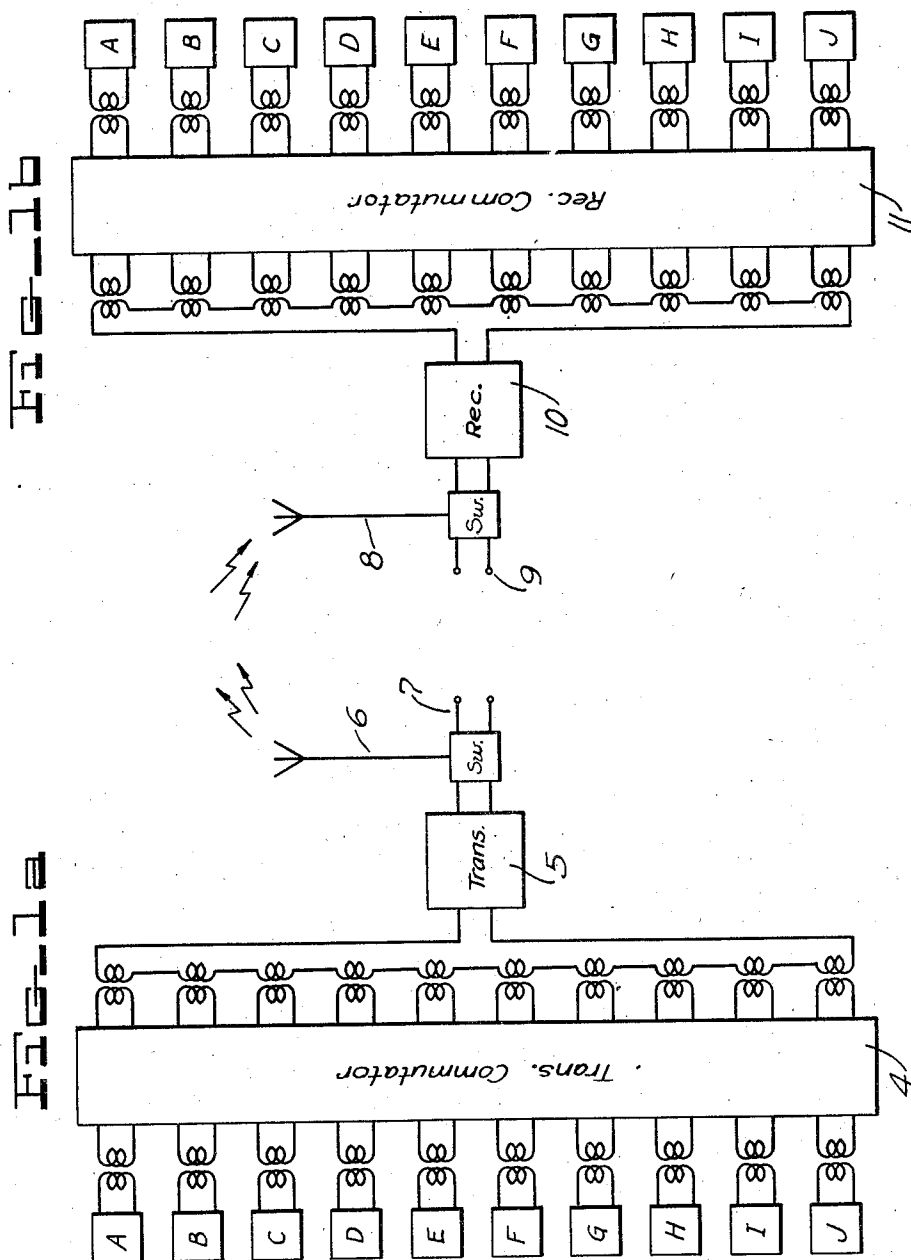
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2,021,743

MULTIPLEX SIGNALING

Filed June 13, 1930

5 Sheets-Sheet 1



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Fig. 2

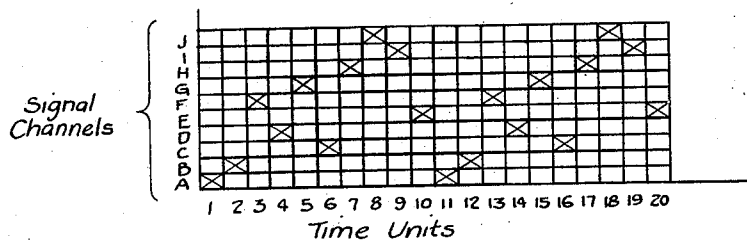


Fig. 3

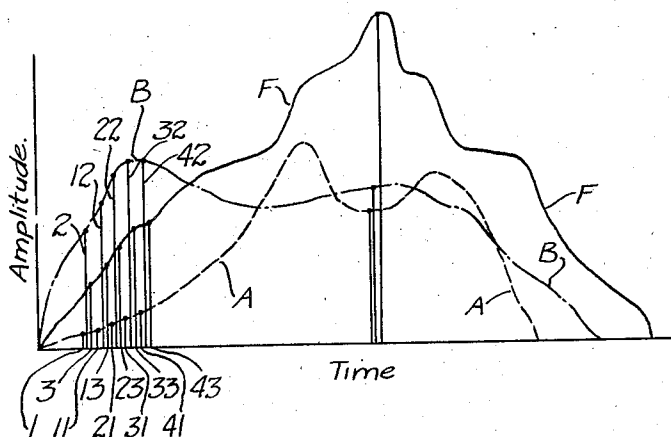
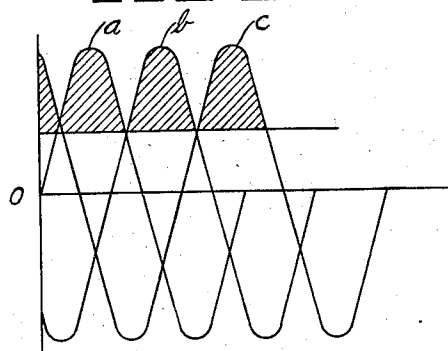


Fig. 5



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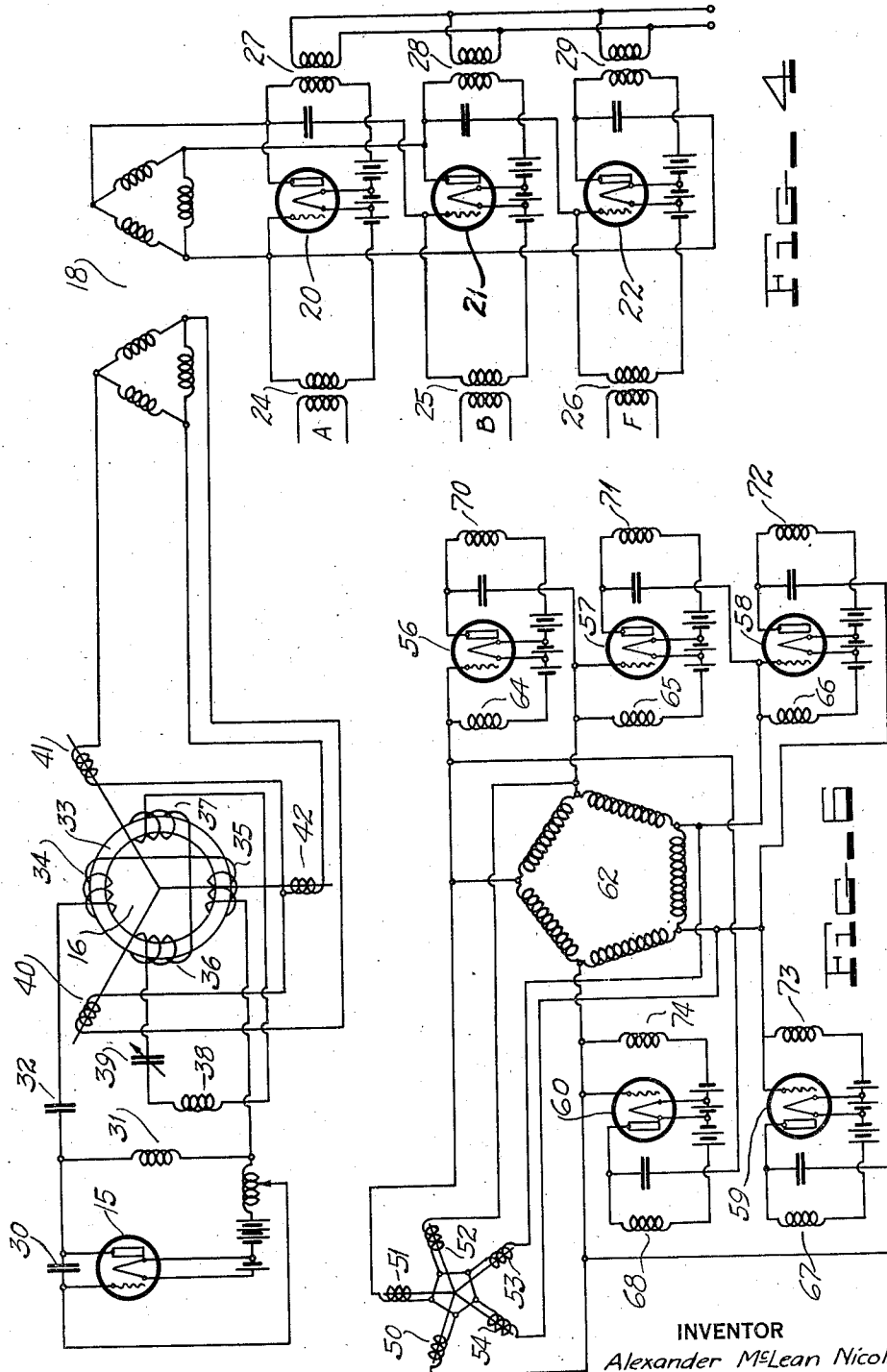
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5 Sheets-Sheet 3



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Fig. 7

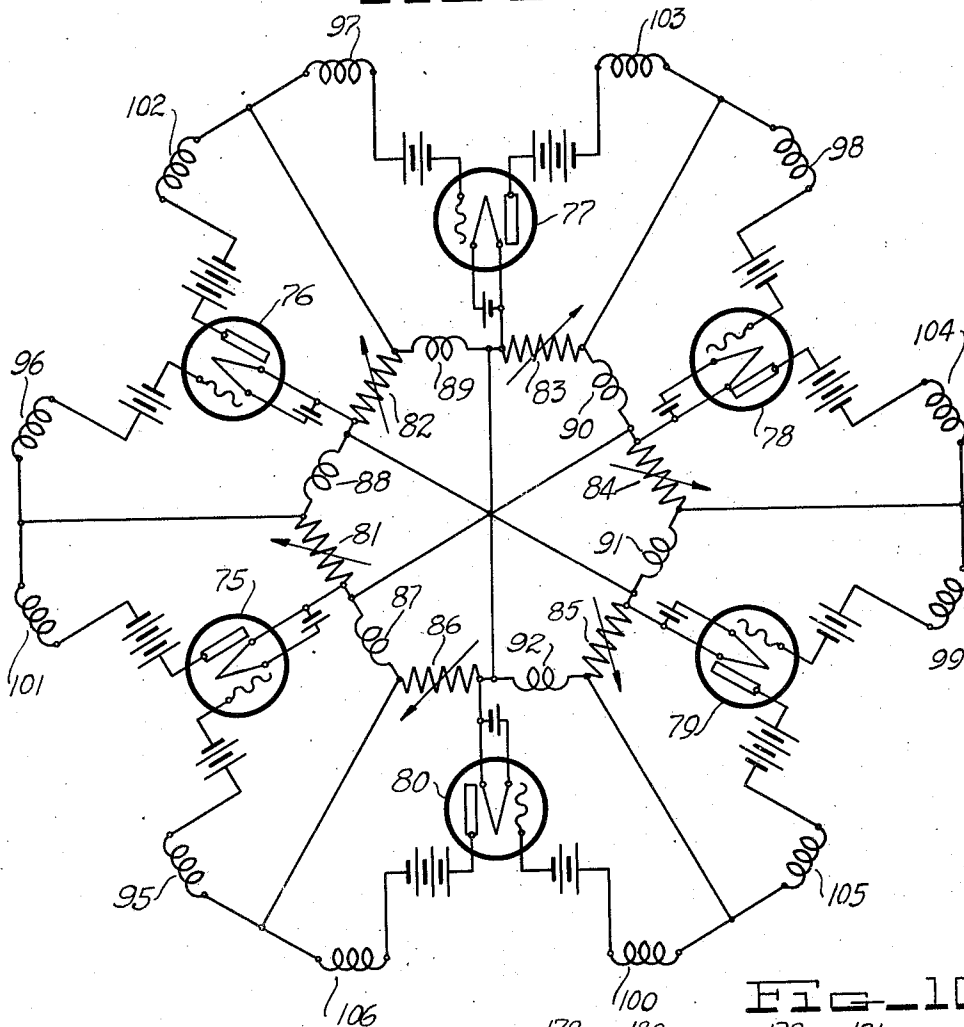


Fig. 8

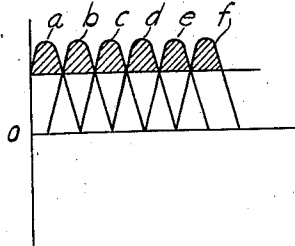
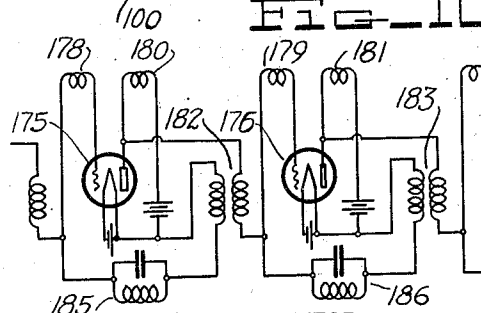


Fig. 10



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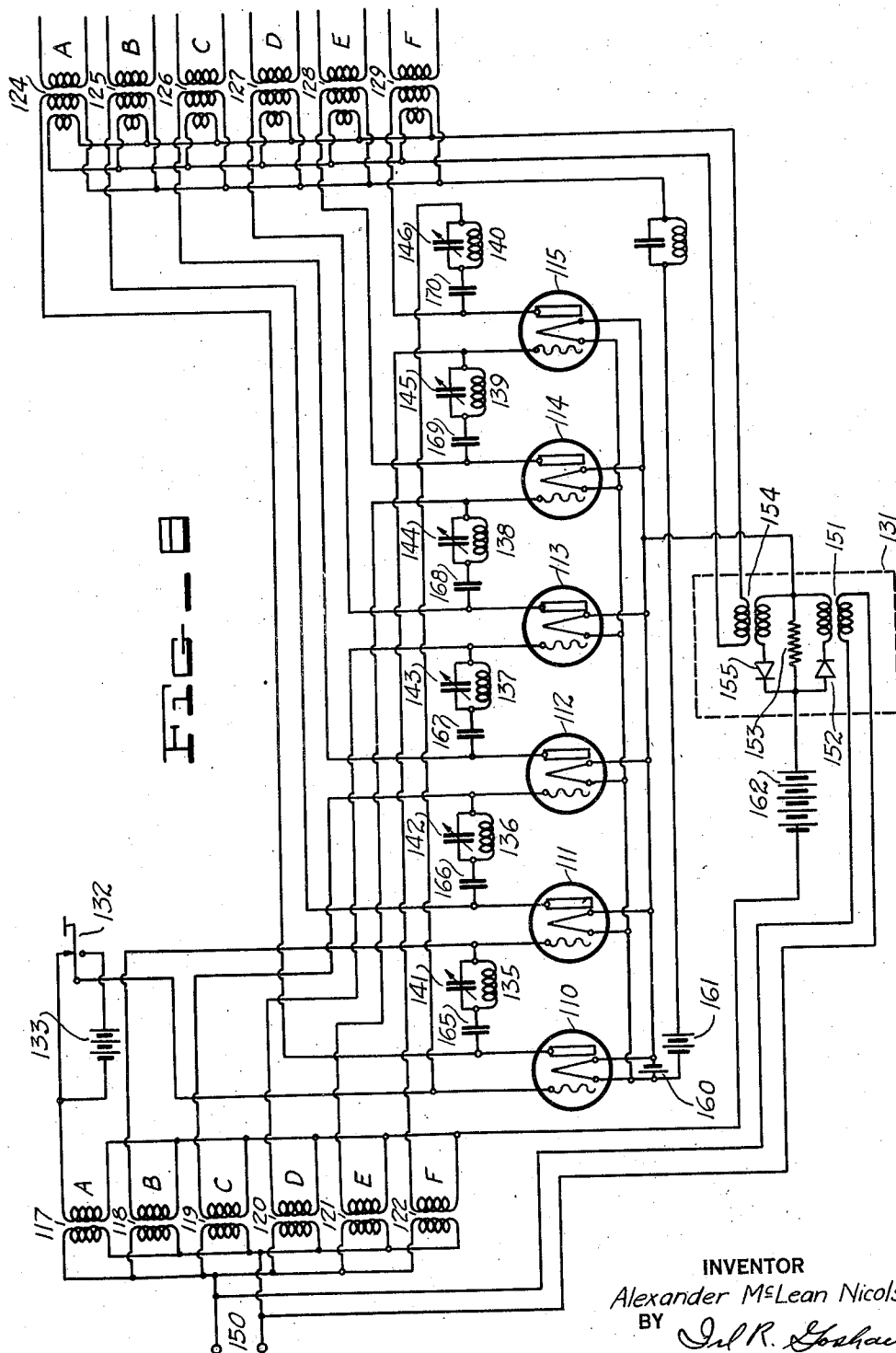
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UNITED STATES PATENT OFFICE

2,021,743

MULTIPLEX SIGNALING

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Application June 13, 1930, Serial No. 460,806

9 Claims. (Cl. 179—15)

This invention relates to multiplex transmission in general, and particularly to the transmission of a plurality of dependent or independent signals over a single channel of wire conductors or of a carrier frequency.

An object of this invention is to transmit an extremely large number of electrical signals over a single communication channel.

Another object of this invention is to obtain an electrical commutator having no mechanically moving parts.

A further object of the invention is to obtain perfect synchronization between electrical commutators separated from one another.

Heretofore, it has been possible to transmit several conversations over a single pair of conductors. Within a certain carrier frequency range having definite limits, a number of broadcasts or independent programs have been transmitted.

Within another frequency range telegraph circuits have been operated to transmit a number of telegraph messages. In substantially all of the above mentioned systems, separation of one signal from the other has been effected through the use of different transmitting or carrier frequencies. For instance, one conversation or signaling channel will have a carrier frequency of 50,000 cycles using a band width, if the signal is sound and both side bands are transmitted, of 12,000 cycles lying between 44,000 and 56,000 cycles. The next carrier frequency channel for sound will necessarily be spaced at least 6,000 cycles from 50,000 cycles to prevent interference between signals. Practically, however, this frequency spacing must be much greater. It is obvious, therefore, that with the carrier frequencies available, the number of signaling channels within the usable range is essentially limited.

It is also known that two-way conversations or two independent transmission channels may be accomplished on the same carrier frequency by using the positive half cycle for the transmission of one signal and the negative half cycle for the transmission of the other signal. Adoption of this method, however, will only double the number of usable channels.

The present invention contemplates obtaining a substantially unlimited number of signaling channels upon either a single carrier frequency or over a single pair of conductors. For telephone use, one central station can serve a large metropolitan area such as New York, that is, it is possible to combine 10 or 15 of the present exchanges into one exchange. Furthermore, this invention permits all broadcasting stations to use

the optimum broadcast frequency, thereby eliminating any controversy as to assignments of preferable portions of the broadcast frequency spectrum.

The invention is based upon time division, time being the sole basis upon which signals are separated from one another instead of upon the basis of frequency separation in which time is only partially involved. It is well known that any signal having energy of a vibratory nature, may be transformed into electrical currents having definite frequencies, the combination of which will form a certain wave shape. Viewing the signal, therefore, from the standpoint of wave shape in the form of a curve, such a signaling curve may be reproduced by the transmission of a certain number of the component parts thereof. In other words, a voice conversation or single words or letters may be transmitted intelligently by the transmission of only a portion of each word or letter or even a portion of the conversation.

The transmission, therefore, of a sufficient number of points upon any curve will reproduce the curve. For instance, a curve of any configuration extending over a length of one inch is divided into 10,000 parts on a horizontal basis. By eliminating 99 parts out of each 100, it is conceivable that the curve can be reproduced sufficiently complete for all practical purposes. If this inch curve be further divided into 1,000,000 points, and every ten thousandth point be reproduced, the same number of points at the same position will occur, reproducing the same curve as when the inch distance was divided into only 10,000 divisions. In the case when the curve was divided into 1,000,000 divisions, however, there is provided space for 9,999 other wave shapes, which can be interpositioned between the 100 points representing the first curve. By repeating the 10,000 division plan 100 times within the inch, the same result is obtained.

From the above brief explanation, which outlines the principle upon which applicant's invention is based, it may be seen that by dividing a signal into sufficiently small increments, it is unnecessary to transmit a large number thereof to make the signal perfectly intelligible when the increments are reproduced thereby providing time to transmit increments of other signals. Any signal which is possible of transformation into electrical vibrations may be transmitted in this manner such as television signals, voice signals, telegraph signals, etc.

A feature of this invention is the use of a thermionic commutator. This commutator has

no mechanical parts whatever and is capable of rotating at a speed corresponding to the speed of transmission of electric current or of the speed of light which is exceedingly faster than any mechanical system may be forced to rotate. With such a commutator, time can be divided into extremely small units or increments. Each unit or increment of this time division may comprise a time channel, the signal to be transmitted being impressed upon one of these time units, and only periodic portions thereof being transmitted at that interval. At the receiver, a similar commutator, rotated in synchrony with the transmitting commutator, connects the time channel circuits and adds the impulses for reception, the continuity of the signals being maintained by the large number of signal portions within definite limits. Between the impulses of any one signal, however, many other channels may be transmitted and received at their respective receivers.

The details of the invention will be more thoroughly understood by reference to the accompanying drawings, in which:

Figures 1a and 1b are diagrammatic drawings of a transmission system and a receiving system, respectively;

Fig. 2 is a signal time chart showing the method of segregating the signal channels into time units;

Fig. 3 is a time curve chart showing how three curves representing wave forms may be transmitted by reproduction of a sufficient number of points thereon;

Fig. 4 is a schematic diagram of a generator-translator circuit as an individual unit;

Fig. 5 is a curve diagram of the currents in the system of Fig. 4;

Fig. 6 is a schematic drawing of a modification of the system of Fig. 4;

Fig. 7 is a circuit arrangement of a combined generator and translator;

Fig. 8 is a circuit arrangement of a modification of the system of Fig. 7 showing a synchronizing circuit used with two thermionic commutators;

Fig. 9 is a current chart of the system of Fig. 8; and

Fig. 10 is a partial schematic drawing of a coupling between tubes which may be used in the systems of Figs. 7 and 8.

Referring to Fig. 1a particularly, signal sources which may be of any type of electrical vibrations constituting particular forms of intelligence, are represented at A to J, inclusive. These channels are shown connected to a transmitting commutator 4, in which they are divided into time units. The output circuits of the commutator are combined and impressed upon transmission apparatus 5, the output circuit of which is connected with a space antenna system 6 or wire conductors 7.

In Fig. 1b a receiving antenna 8 and wire conductors 9 are shown connected to receiving apparatus 10 which impresses its output on a receiving commutator 11 similar to that of the transmitting commutator 4. The references A to J, inclusive, in this figure represent receiving devices of a type appropriate to the reception of the particular signal being transmitted over any channel, and in accordance with the respective signal source in Fig. 1a. In these diagrams it is to be noted that the input to the transmission apparatus 5 is a series arrangement as well as the output of receiver 10, but this is not neces-

sary, as parallel connections will serve as well. The transmitting apparatus may be a high frequency carrier wave or may be simply amplifiers of any type, the operation of which is the same as in electrical transmission systems well known in the art.

In Fig. 2 the signal sources or channels A to J of Figs. 1a and 1b, respectively, are shown along the vertical axis extending horizontally, and their segregations shown along the horizontal axis. Channel A for instance will take the first time unit; signal B the second time unit; signal F the third time unit; and so on as shown in the diagram. These signal sources are handled by a thermionic commutator having an equal number of time channels, two revolutions of which are shown on the chart. This may be modified, of course, by using a commutator having a larger capacity of time channels, only ten of which are employed for the transmission of these ten sources. In that case there would be a space on the chart between the tenth and eleventh unit, which is nine times as large as ten units now shown assuming that the commutator has the same speed. The length of time of transmission of any particular channel is measured along the horizontal co-ordinate and is equal for each signal. This is not essential, however, as one time unit may differ from another as long as the time units are kept in synchronism at the transmitter and receiver. It may be desirable to have varying time units in order to increase the quality of certain signals of a very complex nature.

In Fig. 3, three curves A, B, and F are shown, these curves representing positive half cycles of three wave forms such as speech for instance, which may be the signal sources A, B, and F of the preceding figures. The time units corresponding with the chart of Fig. 2 are shown by the points 1, 2, 3; 11, 12, 13; 21, 22, 23, etc. This diagram illustrates, therefore, that the points 1, 11, 21, 31, 41 . . . n produce the curve A, while points 2, 12, 22, 32 . . . $n+1$, produce the curve B, and points 3, 13, 23, 33 . . . $n+2$ produce the curve F. The signal transmissions have been shown as points on the curve, but in fact are appreciable lengths thereof. Furthermore, for clearness, only a few points have been taken to represent the operation of the system, but it is apparent that by greatly subdividing these signals permitting the transmission of many intermediate portions, a more perfect reproduction is obtainable.

To accomplish this rapid signal dividing, the system shown in Fig. 4 may be used. This system comprises two units, one of which is a three-phase generator source comprising a vacuum tube 15 and quadrature field unit 16 having a delta output transformer 18. The other unit is the translator comprising three vacuum tubes 20, 21, 22, the inputs to which are transformers 24, 25, and 26, and the outputs of which are transformers 27, 28 and 29. Referring to the generator in detail, it is of the type disclosed in R. D. Duncan, Jr., Patent No. 1,578,881, dated March 30, 1926, the oscillator comprising a tube 15, having a feed-back condenser 30 and tuning elements 31 and 32. The oscillator feeds a magnetic circuit 33 having coils 34 and 35 wound thereon. A tuned quadrature circuit is coupled to the magnetic circuit by coils 36 and 37 which is tuned with elements 38 and 39. It is well known that by placing coils at regularly disposed angles, a respective number of currents may be induced in coils thus arranged at the frequency being gen-

erated. In the present generator three phase currents are being induced in windings 40, 41, and 42 disposed 120° apart and connected to the primary winding of delta transformer 18. These three phase currents govern or control the transmission through vacuum tubes 20, 21, and 22, that is, vacuum tube 20 of the translator will be made operative during the positive half cycle of one phase of the control current, while vacuum tube 21 will be operative during the positive half cycle of the second phase, and vacuum tube 22 will be operative during the positive half cycle of the third phase. The three signals, therefore, A, B, and F shown in Fig. 3 arriving in the input transformers 24, 25, and 26, respectively, are each transmitted during one-third of the frequency time of the generated frequency.

For instance, if the frequency is 900 cycles per second, then 900 impulses of each signal are sent during each second but each time unit will be 1/2700 of a second in length. That is, each signal will occupy 1/3 of a second divided into 900 time units of 1/2700 of a second in length. Referring to Fig. 5, the three phase control frequency impulses are shown as *a*, *b*, and *c*. The shaded portions of these curves represent the portion of the three phase currents which are effective in controlling or operating the tubes, since the grids of the tubes are biased sufficiently to prevent any plate current flowing until the positive impulse has reached a value shown by the horizontal line at the intersections of the positive half cycles. Now if phase *a* is impressed on tube 20, this tube will be made operative for 1/2700 of a second and immediately upon cessation of operation, phase *b* will place the tube 21 in an operating condition for 1/2700 of a second. When the tube 21 is made inoperative by the removal of the positive potential, tube 22 immediately becomes operative by virtue of the positive potential placed on its grid by phase *c*. In other words, each tube is made operative by placing intermittently thereon a positive bias such as to operate the tube during a definite period.

Referring to Fig. 6, this modification of the translator of Fig. 4 has five time channels. The coils 50, 51, 52, 53, and 54 have induced therein five phase currents by placing them in the quadrature magnetic field of the generator in Fig. 4. These five phase currents are impressed upon vacuum tubes 56, 57, 58, 59, and 60, respectively, through the pentagonal arranged coupling coils 62. In the inputs of the vacuum tube circuits are secondaries 64, 65, 66, 73, and 74 of input transformers, while in the output circuits of these tubes are primaries 70, 71, 72, 67, and 68 of output transformers. This five time channel system operates in exactly the same manner as the translator of the system of Fig. 4, that is, the grids of the tubes are biased sufficiently to permit operation thereof during the portion of the positive half cycles of the five phase currents above the points of intersection of the phases. This translator, however, will have a capacity of five time channels and if the generator of Fig. 4 produces the same frequency of 900 cycles per second, there will be 900 impulses per second for each channel, each impulse, however, being only 1/4500 of a second in length while the rapid uniform occurrence of each 1/5 will produce effective simultaneous reception.

In Fig. 7 a six time channel combined generator-translator system is illustrated schematically and arranged to represent a mechanical

rotating commutator system. Six vacuum tubes 75 to 80, inclusive, are interconnected successively by variable output impedances 81 to 86 inclusive, and input impedances 87 to 92, respectively. The elements of these tubes are supplied by individual batteries, as shown, with each tube having secondaries 95 to 100, inclusive, of input transformers connected in their respective grid circuits, and primaries 101 to 106 of output transformers connected in their respective output circuits. This circuit is substantially an impulse generator or oscillator. For instance, the grid of tube 75 is made positive in any manner such as by short circuiting the grid battery, momentarily producing in this tube a plate current which rises and falls. This impulse is impressed on the grid of tube 76 through the potential obtained across the coupling impedance 81. After amplification in tube 76 to compensate for any loss in transmission, the impulse is similarly impressed on the grid of tube 77 through coupling impedance 82. In this manner, the impulse is propagated through each tube in succession, and will continue to rotate around the circuit as long as energy is supplied to the vacuum tubes. The speed of rotation of this impulse is determined by the constants of the circuit, but will have a theoretical limit of that of the speed of light. Because of this fact, the impulse frequency may be used in the same manner as the present carrier without a separate carrier source.

Referring to Fig. 9 of the drawings, the shaded portions of curves *a*, *b*, *c*, *d*, *e*, and *f*, represent the plate current in each tube. By continuing the curves of the impulses, it will be noted that an extremely high six phase current frequency is generated by the tubes, although the other portions of the current waves are eliminated by the grid bias on each tube. The shaded portions, however, may be used for transmitting signaling impulses in the same manner as in the system of Figs. 4 and 5. A signal may be impressed upon tube 75 through secondary winding 95 and repeated therethrough into primary winding 101 of the output transformer during the time when the tube 75 is operative. This signal will again be transmitted through this tube after the impulse has been propagated through the other tubes in the system and returned to tube 75. This rotating system, therefore, provides an extremely high speed time dividing commutator entirely electrical. The speed may be controlled by controlling the coupling impedances 81 to 86, inclusive, which actually varies the amplitude of the impulses. If the amplitude of these impulses is made small, the time unit thereof is correspondingly smaller and a more rapid rotation is effected. As each tube controls a time unit or channel, the time units may be varied in length by changing the grid bias on different tubes. An impulse may be increased and a time unit lengthened in a tube by changing the bias to a more efficient operating point, or decreased and a time unit shortened by changing the bias in another direction. Changing circuit constants will also effect the same result. The control impedances 81 to 86 may be connected to a common control means for uni-control operation.

In Fig. 8 a tandem arrangement of a six time channel system is shown with vacuum tubes 110 to 115, inclusive, input transformers 117 to 122, inclusive, and three winding output transformers 124 to 129, inclusive, respectively. This system is a combined generator-translator system similar to the system of Fig. 7, but has a slightly

different principle of operation. There is also included a synchronizer 131, for keeping a receiving commutator in step with a transmitting commutator. In this system a starting switch 132 for placing a positive bias from a battery 133 onto vacuum tube 110 is connected in the grid circuit of this tube only. Six channels A, B, C, D, E, and F having inputs and outputs to the system may correspond with the single channels in the preceding explanatory figures. A feature of this circuit is the delay coupling units 135 to 140 which transfer the impulses from the plate circuits of preceding tubes to the grids of succeeding tubes at a certain time rate. These units have variable condensers 141 to 146, inclusive, for controlling the time delay of the impulses, all of which may be connected to a single control for unitary operation. Blocking condensers 165 to 170, inclusive, segregate the direct current plate and grid circuits.

An impulse generated in the tube 110 by depressing key 132 is transferred to the primary of output transformer 124 and to the grid of tube 111 through delay unit 135. The tuning of this delay circuit determines the time of operation of the tube 111 which in turn transmits the impulse to tube 112. The last tube 115, through circuit 140 transmits the impulse back to tube 110 for obtaining the continuous rotating action. After the first depression of key 132, the grids are all biased by the common battery 162. The operation of this system is practically the same as that of Fig. 7, and may be represented by Fig. 9, except that the generated waves may have differently shaped peaks.

The system in Fig. 8 may be considered a receiving commutator with an input 150 which is a single pair of conductors or the output of a space radio receiving system. The transmission over the circuit is impressed upon the input transformers 117 to 122, inclusive, simultaneously. If tube 110 is made operative by the rotating impulse which removes the heavy bias, the signal arriving through transformer 117 will be transmitted through the tube to the output of transformer 124 which may be connected with a receiving device in accordance with the type of signal being transmitted. Transmission will not occur through any of the other tubes because of the heavy normal bias. When the impulse actuates tube 111, the signal of channel B or B signal will be transmitted to output transformer 125 and to its reproducing device. In this manner each signal will be distributed to its proper receiving device.

The received impulses will also be impressed upon transformer 151 of the synchronizer 131. This transformer has a secondary in series with a one-way rectifier 152 which is shunted by a resistance 153 and the secondary of another transformer 154 in series with a second rectifier 155. In the present system all the filaments of the tubes are supplied from the common filament battery 160, and the plates supplied from a common high potential source 161, and the grids from the common grid biasing potential 162. The grid biasing potential 162 is connected between the grids and filaments through the resistance 153 of the synchronizer shunted by the rectifier circuits just described. This source of potential is constant and remaining constant, provides a certain speed of rotation to the impulse through the tubes. When the impulse from the input 150 is impressed on transformer 151, it is rectified by the rectifier 152 and provides a bias in one par-

ticular direction, for instance, decreasing the bias on the tubes. In this way a slowing up of the speed of propagation of the impulse around the circuit is obtained. To neutralize this effect, an equal impulse is impressed on the resistance 153 through the transformer 154 which is obtained from the third windings of the output transformers 124 to 129, inclusive. The increased potential derived from transformer 151 will be neutralized by the potential obtained from transformer 154 if, and when the output impulses are in exact time relationship with those being received at 150. Any variation of the impulses being received at 150 with respect to the impulses being generated in the tubes, will be evidenced by a bias in one direction or the other in the synchronizer 131. That is, if the system of Fig. 8 is rotating too rapidly, there will be a differential bias produced in the synchronizer to decrease the speed at which the impulse is transmitted from tube to tube. This is caused by the phase differential of impulses arriving at the two transformers 151 and 154 providing a directional bias, depending upon the time of arrival. If the system in Fig. 8 is completely out of step, it may be started and stopped by the key 132, to obtain original synchronism, after which the synchronizer 131 will maintain the commutators in synchronism.

In Fig. 10 a modification of the coupling between tubes of a rotating electrical commutator is shown. The two tubes 175 and 176 may be two of a series such as illustrated in Figs. 7 and 8, with their respective input circuits 178 and 179, and output circuits 180 and 181. The feature involved in this circuit is that the circulating impulse is fed back from an operating tube in a 180 degree phase relationship through transformers 182 and 183. The returning impulse is delayed in its blocking action on the grids by tuned circuits 185 and 186, to obtain any desired speed of commutation. This feed back prevents any tendency of a tube to oscillate, and eliminates the need of a heavy grid bias. Each tube transmits its impulse and then automatically blocks itself until further actuated by a positive impulse.

The systems above described have been shown transmitting signals in one direction, but two-way communication is obvious over the same system by the use of hybrid coils for segregating the input and output circuits of any one of the tubes of the thermionic commutators. That is, the same tube may serve as a repeater in each direction, and any time channel may serve as a two-way signaling channel in the same manner as any telephone line.

Although this invention has been disclosed in its preferred embodiments, it is obvious that there are many modifications which may be accomplished within the scope of the appended claims.

What is claimed is:

1. In a multiplex communication system, a transmitting station, a receiving station, a plurality of signal sources at said transmitting station, a corresponding plurality of receiving devices at said receiving station, a thermionic commutator at each of said stations comprising a plurality of thermionic devices arranged in tandem, said devices being made operative in a serial order at mutually exclusive intervals, means for impressing on each of said devices a signal from one of said signal sources, and means at said receiver for connecting one of said receiving devices to each of said electronic devices at said receiver, said thermionic commutator at

said receiver distributing the signals from said signal sources to respective receiving devices.

2. A thermionic commutator comprising a plurality of interconnected thermionic devices arranged in tandem, means for transmitting a current impulse through each of said devices in series, and means for blocking each of said devices immediately after transmission of said impulse therethrough.

3. A thermionic commutator in accordance with claim 2, in which said last mentioned means includes a feed back transformer for each of said devices.

4. A thermionic commutator comprising a plurality of thermionic devices connected in cyclic order, means for directly connecting the output of the preceding device with the input of the succeeding device, said means including inductive and capacitive elements for delaying the transmission of an impulse therebetween a definite time interval, and means for initiating an impulse in one of said devices.

5. A thermionic commutator comprising a plurality of interconnected thermionic devices arranged in cyclic order, delay circuits including inductive and capacitive elements connected directly to each of said devices for delaying the transmission of an impulse through each device at mutually exclusive intervals, and means for biasing the control element of each of said devices, the adjustment of said biasing means and said delay circuits varying the transmission of impulses through said devices.

6. In a multiplex transmission system, a plurality of thermionic devices located at one station, a duplicate plurality of thermionic devices located at a second station, delay circuits intermediate each of said devices at each of said stations for delaying the transmission of an impulse therebetween, means for biasing said thermionic devices at said second station, the adjustment of said biasing means and said delay circuits delaying the transmission of said impulses through said devices, means for varying

the bias on said devices by the impulses generated at said second station, and means for varying the bias of said devices by the impulses generated at said first station the impulses generated at said second station neutralizing the impulses generated at said first station and producing no change in bias on the devices at said second station when the generation of impulses at said first station is in synchronism with the generation of impulses at said second station.

7. In an electrical communication system, two stations, a plurality of signaling sources at said two stations, a corresponding plurality of electronic devices arranged in cyclic order located at each of said stations, said devices being operative at mutually exclusive intervals, delay circuits at each station for directly connecting the output of the preceding device with the input of the succeeding device, respectively, and means for transmitting any one signal through any one of said vacuum tubes at each of said stations.

8. In an electrical communication system, two stations, corresponding pluralities of individual electronic devices connected in cyclic order located at each of said stations, means for operating said devices in serial order in synchronism at discrete intervals, delay circuits at each station for directly connecting the output of the preceding device with the input of the succeeding device, respectively, a plurality of signal sources, and means for transmitting the signals from said sources over a pair of said devices in a definite order.

9. In a multiplex communication system, a plurality of thermionic devices mutually connected in cyclic order, means for initiating a rotating electrical impulse in one of said devices, delay circuits directly connected to the output of the preceding device and the input of the succeeding device for circulating said impulses through said devices at a super-audible frequency at mutually exclusive intervals, and means for transmitting a plurality of signals on said frequency.

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