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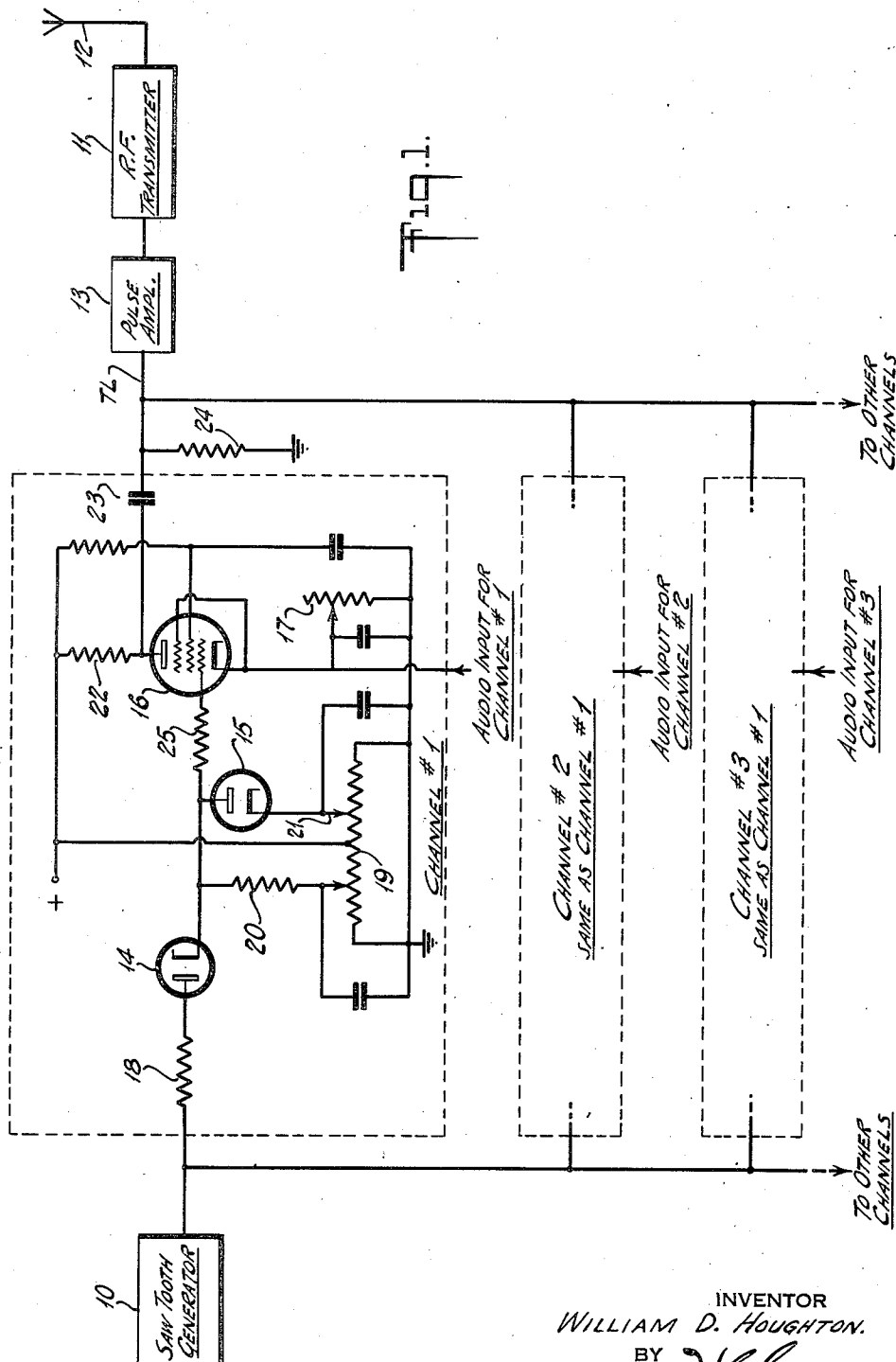
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2,420,374

PULSE MULTIPLEX TRANSMISSION SYSTEM

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2 Sheets-Sheet 1



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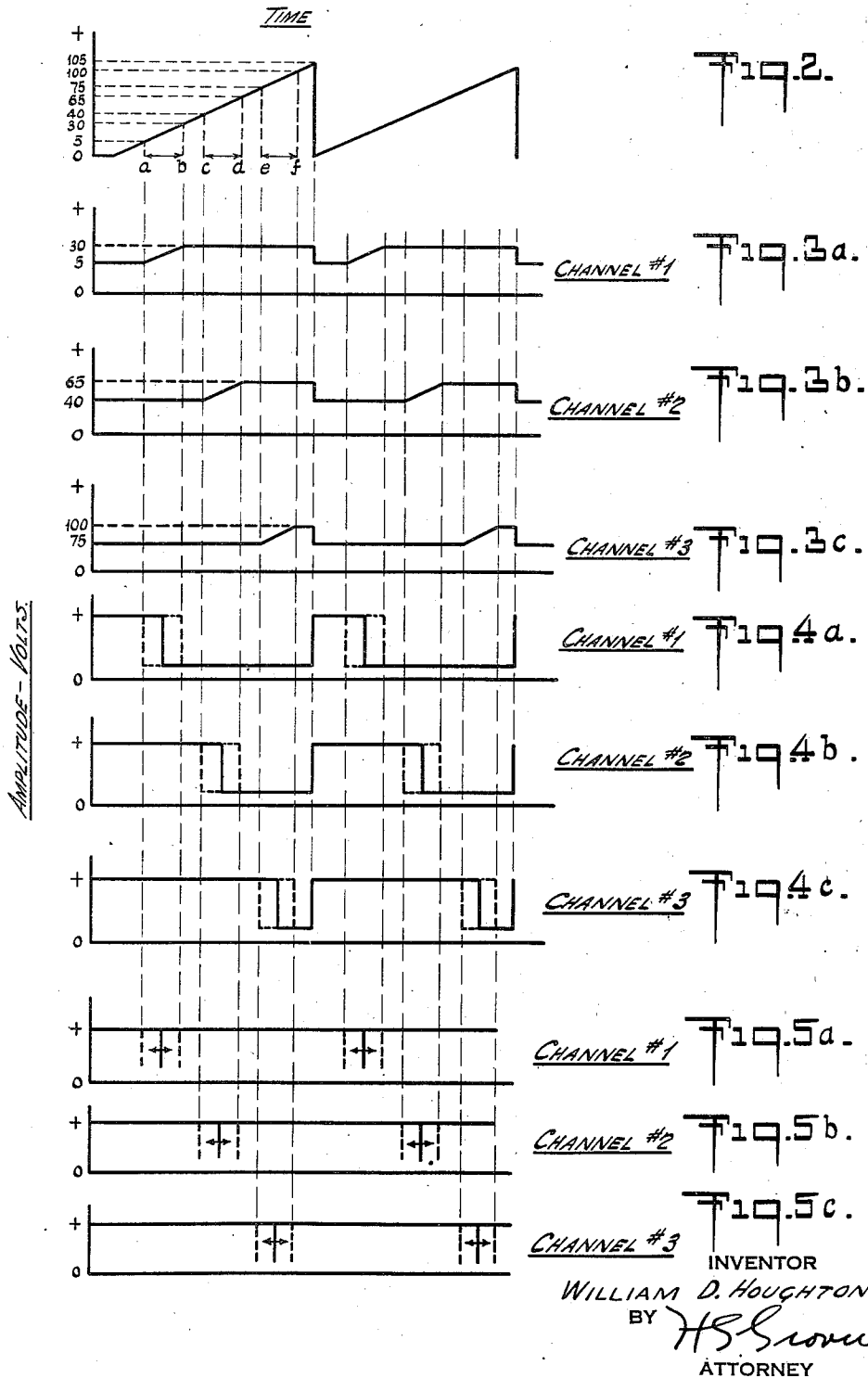
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UNITED STATES PATENT OFFICE

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PULSE MULTIPLEX TRANSMISSION
SYSTEM

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8 Claims. (Cl. 179—15)

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This invention relates to improvements in multi-channel transmitting systems, sometimes referred to as multiplex systems.

An object of the present invention is to provide a simplified and relatively inexpensive transmitting system for assigning a transmission circuit consecutively to a plurality of channels for very short intervals of time, and which requires appreciably less power to operate than conventional multiplex systems.

Another object is to electronically distribute the individually modulated signals from a plurality of channels to a common transmission circuit in a multiplex system without permitting overlapping in the channels due to undesirable overmodulation.

A further object is to provide an improved multiplex radio transmitting system having a plurality of channels sending out over a common transmission circuit separately modulated trains of pulses, each pulse of which is of short duration of the order of one microsecond and less.

A further object is to provide a multiplex pulse type communication system in which the transmitting channels are supplied in common with a saw-tooth voltage wave and the different channels provided with rectifier tubes for selecting different nonoverlapping time portions of the saw-tooth wave which constitute the operating times assigned to the channels.

A still further object is to provide an improved pulse type multiplex system in which the pulses transmitted from each channel are modulated as to timing in accordance with the instantaneous value of the modulation voltage, and in which all channels are synchronously controlled by a common saw-tooth wave generator.

In brief, the improved multi-channel transmitting system of the invention comprises a plurality of channels producing short duration pulses and individually modulated by the signals to be transmitted. All channels are fed with a common saw-tooth voltage wave. Each channel includes a pair of rectifier diode tubes for selecting a certain portion of the linear slope of the saw-tooth voltage wave as the operating time assigned to that channel. The pair of diodes in each channel defines the operating voltage levels of the particular portion of the saw-tooth voltage which is assigned to that channel. The different channels have different assigned nonoverlapping portions on the linear slope of saw-tooth voltage wave. Stated in other words, the operating voltage levels are different for the different channels. One of the diodes in each channel is coupled to the source of saw-tooth voltage waves and is so biased that it does not begin to conduct until the saw-tooth voltage wave has reached the particular voltage level assigned to that channel. The other diode in each channel

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is so arranged that it permits only a desired maximum voltage value to be built up across the first diode. Each channel is also provided with a pentode tube to different electrodes of which are supplied the modulation voltages and the operating voltages corresponding to the region of the saw-tooth wave assigned to that channel. This pentode tube is so biased and arranged that the region between the point of anode current cut-off and the point at which anode current limiting occurs is small compared to the operating voltage region of the saw-tooth wave assigned to the channel containing this tube, as a result of which there is a sharp rate of change of current in the pentode. An output pulse will therefore be produced in each pentode once for each cycle of the saw-tooth wave and the starting time of this pulse will vary in dependence upon the instantaneous value of the modulating voltage. By differentiating and utilizing only the starting or leading edge of this output pulse from the pentode of each channel, there are obtained variably positioned very short duration impulses at the frequency of the saw-tooth wave. These impulses will vary in time between points corresponding to the operating voltage levels assigned to the channel. The differentiated impulses from all channels are utilized in a common transmission circuit to control the transmission of corresponding impulses of high frequency energy.

Other objects and features of the invention will appear from a reading of the following description which is accompanied by a drawing, wherein:

Fig. 1 illustrates a multiplex transmitting system in accordance with the invention;

Fig. 2 is a graph of the saw-tooth voltage wave which is applied to all of the channels of Fig. 1, and shows how different portions of the saw-tooth voltage wave are assigned to the different channels;

Figs. 3a, 3b and 3c graphically illustrate curves of the voltages applied to the control grids of the different pentodes of a three channel transmitting system of the invention;

Figs. 4a, 4b and 4c graphically illustrate the anode voltage curves of the pentodes in the different transmitting channels of a three channel system of the invention; and

Figs. 5a, 5b and 5c illustrate the effective variably positioned impulses from the three transmitting channels as a result of differentiating the output pulses from the different pentodes.

Referring to Fig. 1, there is shown a multi-channel or multiplex transmitting system comprising three channels 1, 2 and 3, each modulated by an independent sound or audio program and all locked together by means of a common saw-tooth generator 10 so that their pulses occupy different time periods but occur at the same fre-

quency. All three channels are coupled to a common transmission line TL extending to a radio frequency transmitter 11 and an associated radiating antenna 12. A pulse amplifier 13 located between the line TL and the transmitter 11 serves to amplify the impulses impressed on the line from the different channels. The antenna 12 may be any suitable structure, preferably a directive type of antenna which is pointed to be most effective toward the remote receiver (not shown).

The three channels are similar in construction and each includes a pair of diode vacuum tubes 14 and 15 and a pentode vacuum tube 16. The diode tubes 14 and 15 are biased to select the operating voltage levels for each channel, and these voltages are applied to the control grid of the pentode 16. The pentode tube 16 is in effect a cathode-biased modulator tube having the audio modulation supplied to its cathode across the cathode bias resistor 17. It should be noted that the saw-tooth generator 10 is coupled in common to the inputs of all the channels, and it is this generator which controls the frequency of the pulses from the different channels.

Since all channels contain similarly arranged elements, only one of the channels (to wit, channel 1) has its circuit elements shown in detail. Fig. 2 illustrates by way of example the saw-tooth voltage wave generated by 10 and applied to the different channels of Fig. 1. The saw-tooth voltage is fed to the diodes 14 of all three channels through their respective resistors 18. The cathode of the diode 14 is given a positive bias by virtue of the tap on the potentiometer 19 so that it will not conduct until a predetermined potential on the saw-tooth wave is reached. After this predetermined potential is reached, the diode 14 will conduct and develop a voltage across the resistor 20 which will vary in proportion to the saw-tooth voltage applied to the resistor 18. The cathode bias on the diode 15 is so set by means of the tap 21 on the potentiometer 19 that tube 15 will not conduct until the voltage developed across resistor 20 and applied to the anode of the diode 15 reaches another predetermined voltage value. As the voltage across resistor 20 tends to increase above this last value, due to the fact that the saw-tooth wave is increasing, the diode tube 15 will carry more and more current and thus maintain the voltage developed across resistor 20 practically constant at a value equal to the maximum voltage value assigned to that particular channel. Putting it in other words, tube 14 will conduct when the saw-tooth wave reaches a desired voltage level determined by the adjustment of resistor 20 on resistor 19, but only a desired maximum voltage developed across the resistor 20 is effective on the control grid of the pentode 16 and any greater voltage than this desired maximum will be short-circuited by diode 15. It is desired that the different channels have different operating voltage regions selected for them, and that these different voltage regions have substantially the same latitude of voltage. For example, if the saw-tooth voltage wave varies from zero volts to 105 volts maximum, and only a three channel transmitting system is employed, each of the three channels will operate over different voltage regions. Channel 1 can operate over the region of, let us say, five to thirty volts. Channel 2 can operate over the region of forty to sixty-five volts. Channel 3 can operate over the region of seventy-five to one hundred volts on the saw-tooth wave. Thus channel 1 will occupy a time

interval equivalent to $a-b$ on the saw-tooth wave of Fig. 2, while channel 2 will occupy a different time interval equivalent to $c-d$ on the saw-tooth of Fig. 2, and channel 3 will occupy the time interval equivalent to $e-f$ of the saw-tooth wave of Fig. 2. It will be seen that different channels have different assigned non-overlapping portions of the linear slope of the saw-tooth wave, and that the different channels have the same latitude of voltage change, in this case twenty-five volts difference in the operating voltage levels in each channel.

Fig. 3a graphically illustrates the shape of the voltage wave which is applied to the control grid of the pentode tube 16 of Fig. 1. Fig. 3b graphically illustrates the shape of the voltage wave applied to the control grid of the pentode of channel 2. Fig. 3c illustrates the shape of the voltage wave applied to the control grid of the pentode of Fig. 3. It is assumed, of course, in plotting the curves of Figs. 3a, 3b and 3c that the bias on the tube 16 is set so that it will not normally conduct.

The pentode tube 16 is so biased that it will conduct midway between the maximum and minimum voltage levels assigned for its particular channel, in the absence of modulating voltage applied to its cathode. Stated in other words, the pentode tube 16 will conduct at the center of the operating voltage region chosen for its own channel when there is no applied modulating voltage. Thus, under the condition just described, the pentode tube 16 for channel 1 will conduct midway between points a and b on Fig. 2, while the pentode tube for channel 2 will conduct midway between the points c and d , and the pentode tube for channel 3 will conduct midway between the points e and f .

The modulating voltage applied to the cathode of the pentode tube 16 varies the cathode bias. Beyond the maximum voltage limit for tube 16 when the modulating voltage is in the positive direction, the tube 16 will cease conducting because the positive voltage on the cathode will exceed the positive voltage on the control grid and thus bias the control grid in a negative direction and the anode current will be cut off. Below the minimum voltage limit for tube 16, when the modulating voltage is in the negative direction, the tube 16 will continue to conduct but there will be no abrupt change in the current of the tube due to the limiting action of the tube. The tube 16 is so arranged that the region between the point of anode current cut-off and the point at which anode current limiting occurs (at this last point the grid potential goes to zero) is small compared to the operating voltage region of the saw-tooth wave assigned to the particular channel. This is achieved by reducing the screen grid voltage on the pentode tube. Stated in other words, if there is a twenty-five volt region assigned to each channel (as assumed above), the tube 16 in each channel should require approximately only two volts of this region to go from anode current cut-off to anode current limiting. The term "limiting" as used herein refers to that condition at which maximum anode current flows through the tube when there is zero grid potential. This action produces a sharp rate of change of current flow through the pentode tube 16. The resistor 25 is employed to reduce grid current in the tube 16. It will be understood, of course, that the pentode tubes in the different channels are differently biased so that they oper-

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ate in the foregoing manner in the different voltage regions assigned to the different channels.

Figs. 4a, 4b and 4c respectively illustrate the anode voltage curves developed across resistor 22 for the pentodes in the three different channels. The dotted lines in each of the figures 4a, 4b and 4c indicate the limits of the region in each channel between which the voltage pulse developed in the output of the pentode can decrease from maximum to minimum. The particular position at which this occurs depends upon the instantaneous modulating voltage applied to the cathode of the pentode tube. It will thus be seen that the sharp rate of change of current flowing through the pentode of channel 1 as indicated in Fig. 4a occurs at a position between points *a* and *b*. The particular position at which this sharp rate of change of current through the pentode of channel 2 occurs, as indicated in Fig. 4b, is between points *c* and *d*. The particular position at which the sharp rate of change of current flow through the pentode of channel 3 occurs, as shown in Fig. 4c, is between points *e* and *f*. These time intervals are spaced apart and do not overlap, for which reason it is impossible for over-modulation of one channel to cause this sharp rate of change from the pentode to move into the space occupied by an adjacent channel.

Each channel is provided with a condenser 23 which together with a resistor 24, the latter being common to the outputs of all channels, constitutes a differentiator circuit. Differentiator circuit 23, 24 converts the sharp rate of change of current in the pentode tube in each channel to a very sharp impulse which flows over the common transmission circuit TL and is amplified in pulse amplifier 13 before being passed onto the radio frequency transmitter 11. This transmitter 11 is normally non-conducting and responds to a pulse of current from the amplifier 13 to produce a corresponding pulse of radio frequency energy which is radiated over the antenna 12.

The solid vertical line of Fig. 5a indicates the differentiated pulse across resistor 24 obtainable from channel 1, which is supplied to the transmission line TL. The double arrow on this impulse of Fig. 5a indicates that it may occur at various points between time intervals *a* and *b*, depending upon the instantaneous modulating voltage on the cathode of the pentode. Similar differentiated impulses for channels 2 and 3 are illustrated respectively in Figs. 5b and 5c. It should be understood that the differentiated pulse in the positive direction which occurs on sharp increase of current flow through the pentodes is not shown in Figs. 5a 5b and 5c because these pulses are not finally utilized. It is only the leading or starting edge of the output pulse which is differentiated by 23, 24 which is utilized, and it is this leading or starting edge which is variable in position in dependence upon the instantaneous modulating voltage.

For each cycle of the saw-tooth wave of Fig. 2 there is thus produced only one pulse in the output of each modulator pentode tube in each channel and the position of this pulse over the assigned region for that channel depends upon the instantaneous cathode bias, in turn controlled by the modulating voltage. By amplitude modulating the cathode of the pentode at an audio rate, the impulses obtained from differentiation of the leading edges of the output pulses from the pentodes in the different channels will vary in time between points corresponding to the different assigned non-overlapping portions on

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the linear slope of the saw-tooth wave. The repetition rate of the impulses derived from each channel is just equal to the frequency of the saw-tooth wave and any number of channels can be utilized to occupy the space corresponding in time to one cycle of the saw-tooth wave, although only three channels have been assumed for the purpose of describing the operation of the invention.

One advantage of the present invention mentioned herein by way of example, lies in the fact that the diode circuits employed in the channels are relatively inexpensive means for selecting or assigning the positions of the channels in a multiplex system and they use considerably less power than conventional apparatus.

What is claimed is:

1. A multi-channel transmitting system comprising a plurality of channels, a saw-tooth wave generator coupled in common to the inputs of said channels and supplying saw-tooth waves thereto, and a pair of rectifier selector tube circuits in circuit with each of said channels for selecting different operating voltage regions corresponding to different non-overlapping portions on the linear slope of the saw-tooth wave, a connection from the anode of one rectifier tube in circuit with each channel to said saw-tooth generator, a direct connection from the cathode of said one rectifier tube in each channel to the anode of the other rectifier tube in the same channel, and means for differently biasing the cathodes of the two rectifier tubes in each channel such that the first rectifier tube passes current before the second rectifier tube, a grid-controlled electron discharge device in each channel controlled by the rectifier selector tubes in that channel, and a common output circuit for all grid-controlled electron discharge devices.

2. A multi-channel transmitting system comprising a plurality of channels, a triangular wave generator coupled in common to the inputs of said channels, a first rectifier in circuit with each channel and adjusted to pass current at a predetermined minimum voltage level on the slope of the triangular input wave, a second rectifier in circuit with each channel and adjusted to limit the maximum voltage developed by said first rectifier, and a normally non-conducting pentode tube in each channel having a grid electrode connected to both rectifiers and arranged to become operative in the region between said minimum and maximum voltage values, the rectifiers associated with the different channels being adjusted to operate at different voltage levels on the slope of the triangular input wave.

3. A multi-channel transmitting system comprising a plurality of channels, a triangular wave generator coupled in common to the inputs of said channels, a first rectifier in circuit with each channel and adjusted to pass current at a predetermined minimum voltage level on the slope of the triangular input wave, a second rectifier in circuit with each channel and adjusted to limit the maximum voltage developed by said first rectifier, and a pentode tube in each channel having its input circuit connected to both rectifiers in the same channel and arranged to be operative in the region between said minimum and maximum voltage values, the rectifiers associated with the different channels being adjusted to operate at different voltage levels on the slope of the triangular input wave, a cathode bias resistor for said pentode tube, different audio modulation circuits coupled across the cathode bias resistors of the different pentode tubes in said channels,

whereby the output from the pentode tube of each channel is a pulse whose occurrence time over the region assigned to each channel depends upon the instantaneous modulation voltage, means for differentiating the output pulses from said channels, and a common transmission circuit coupled to the outputs of said channels.

4. A multi-channel transmitting system comprising a plurality of channels, a triangular wave generator coupled in common to the inputs of said channels, a first rectifier in circuit with each channel and adjusted to pass current at a predetermined minimum voltage level on the slope of the triangular input wave, a second rectifier in circuit with each channel and adjusted to limit the maximum voltage developed by said first rectifier, and a pentode tube in each channel having its input circuit connected to both rectifiers in the same channel and arranged to be operative in the region between said minimum and maximum voltage values, the rectifiers in the different channels being adjusted to operate at different voltage levels on the slope of the triangular input wave, a cathode bias resistor for said pentode tube, different audio modulation circuits coupled across the cathode bias resistors of the different pentode tubes in said channels, whereby the output from the pentode tubes of each channel is a pulse of variable occurrence time depending upon the instantaneous modulation voltage, means for differentiating the output pulses from said channels, a common transmission circuit coupled to the outputs of said channels, and a radio frequency transmitter in said transmission circuit and responsive to the impulses produced by the differentiation of the leading edges of the output pulses from the pentodes of said channels.

5. A multiplex time-division system comprising a plurality of channels, a generator supplying a triangular wave to the inputs of said channels, a normally non-conductive selector circuit associated with each channel said selector circuit comprising a rectifier, means differentially biasing the selector circuits associated with the different channels to thereby cause said channels to become operative at different times in the cycle of the triangular shaped input wave, a pentode vacuum tube in each channel to which is supplied the output from its associated selector circuit, said pentode tube being biased to produce a pulse in its output each time its associated selector circuit becomes conductive, a common transmission circuit coupled to the outputs of the pentode tubes of all said channels, and means positioned between said pentodes and said common transmission circuit for differentiating the pulses produced by said pentode tubes.

6. A multiplex time-division system comprising a plurality of channels, a generator supplying a triangular wave to the inputs of said channels, a selector circuit associated with each channel, said selector circuit comprising a rectifier, means differentially biasing the selector circuits associated with the different channels to thereby cause said channels to become operative at different times in the cycle of the triangular shaped input wave, a cathode-biased pentode tube in each channel to which is supplied the output from the selector circuit of the same channel, said pentode tube having a cathode bias resistor, separate audio modulation circuits coupled across the cathode bias resistors of the pentode tubes of the different

channels, and a transmission circuit coupled in common to the outputs of said pentode tubes.

7. A multi-channel transmitting system comprising a plurality of channels, a triangular wave generator coupled in common to the inputs of said channels, a first rectifier circuit associated with each channel and adjusted to pass current at a predetermined minimum voltage level on the slope of the triangular input wave, a second rectifier circuit associated with each channel and adjusted to limit the maximum voltage developed by said first rectifier circuit, and a pentode tube in each channel having its input circuit connected to both rectifiers in the same channel and arranged to be operative in the region between said minimum and maximum voltage values, the rectifier circuits associated with the different channels being adjusted to operate at different voltage levels on the slope of the triangular input wave, a cathode bias resistor for said pentode tube, different audio modulation circuits coupled across the cathode bias resistors of the different pentode tubes in said channels, the pentode tube in each channel being biased to become conductive at the center of the operating voltage region selected for that channel in the absence of modulating voltage, whereby the output from the pentode tube of each channel is a pulse of variable occurrence time depending upon the instantaneous modulation voltage, means for differentiating the output pulses from said channels, and a common transmission circuit coupled to the outputs of said channels.

8. A multiplex time-division system comprising a plurality of channels, a generator supplying a triangular wave to the inputs of said channels, a selector circuit associated with each channel, said selector circuit comprising a rectifier, means differentially biasing the selector circuits associated with the different channels to cause said channels to become operative at different times in the cycle of the triangular shaped input wave, a cathode-biased pentode tube in each channel to which is supplied the output from the selector circuit of the same channel, said pentode tube having a cathode bias resistor, separate audio modulation circuits coupled across the cathode bias resistors of the pentode tubes of the different channels, the pentode tube in each channel being biased to become conductive at the center of the operating region selected for that channel in the absence of modulating voltage, and a transmission circuit coupled in common to the outputs of said pentode tubes.

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