July 2, 1946. W. A. S. BUTEMENT ET AL 2,403,210

MULTIPLEX PULSE MODULATION SYSTEM

Filed Feb. 14, 1944 4 Sheets-Sheet 1

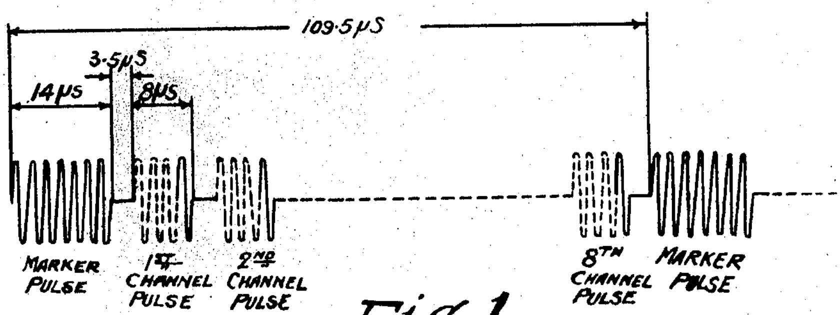

Fig. 1.

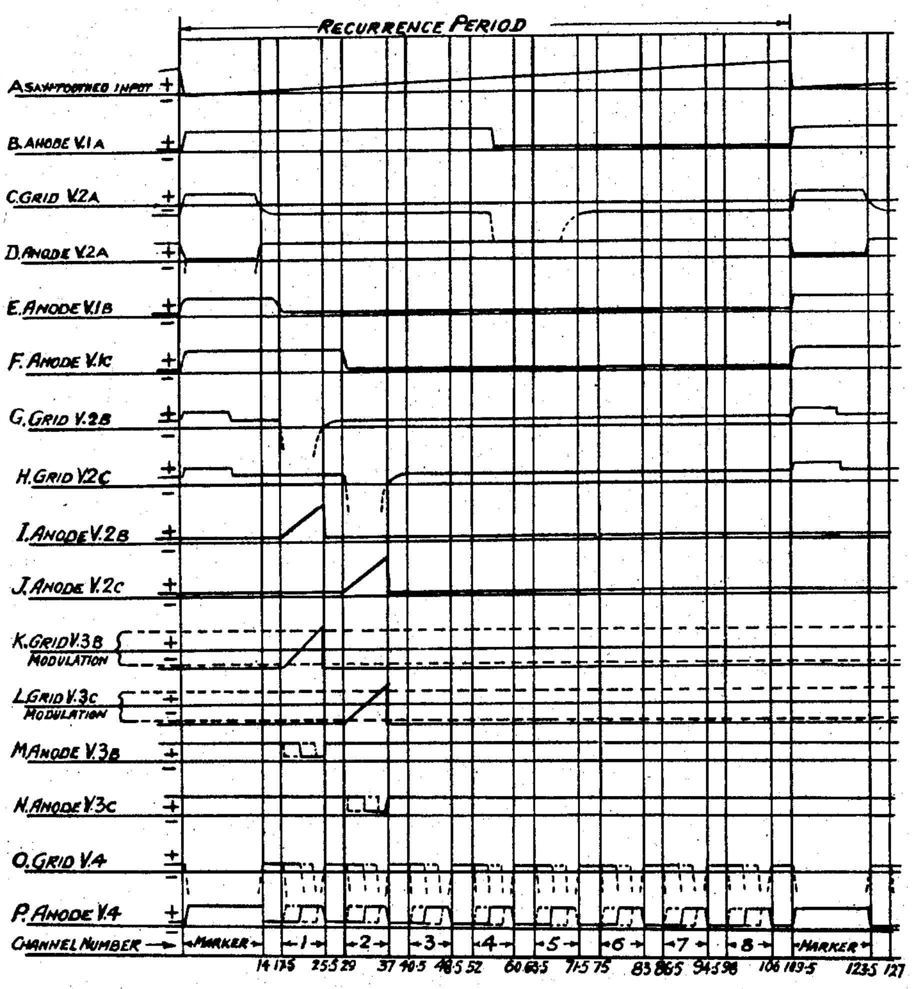

Fig. 3.

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MULTIPLEX PULSE MODULATION SYSTEM

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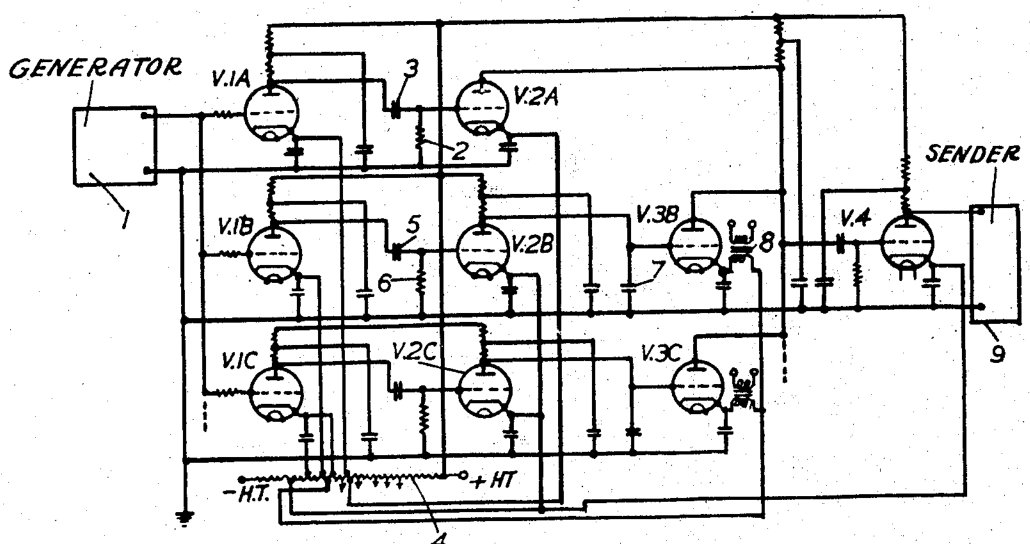

Fig. 2.

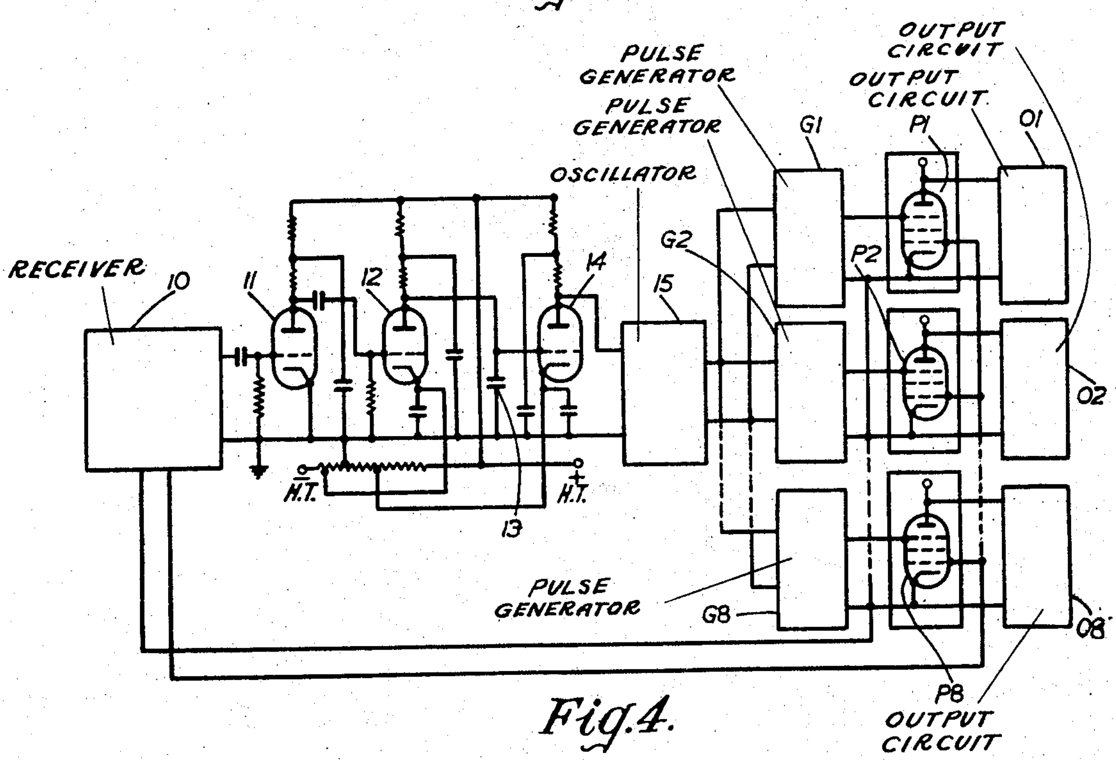

Fig. 4.

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MULTIPLEX PULSE MODULATION SYSTEM

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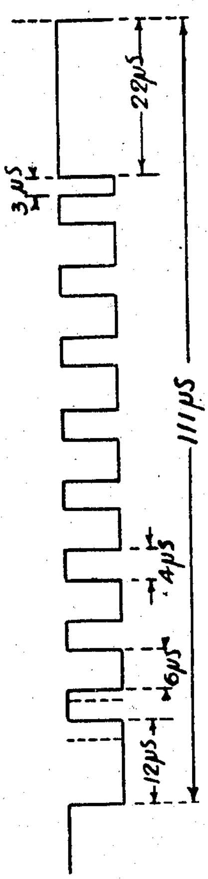

Fig. 5.

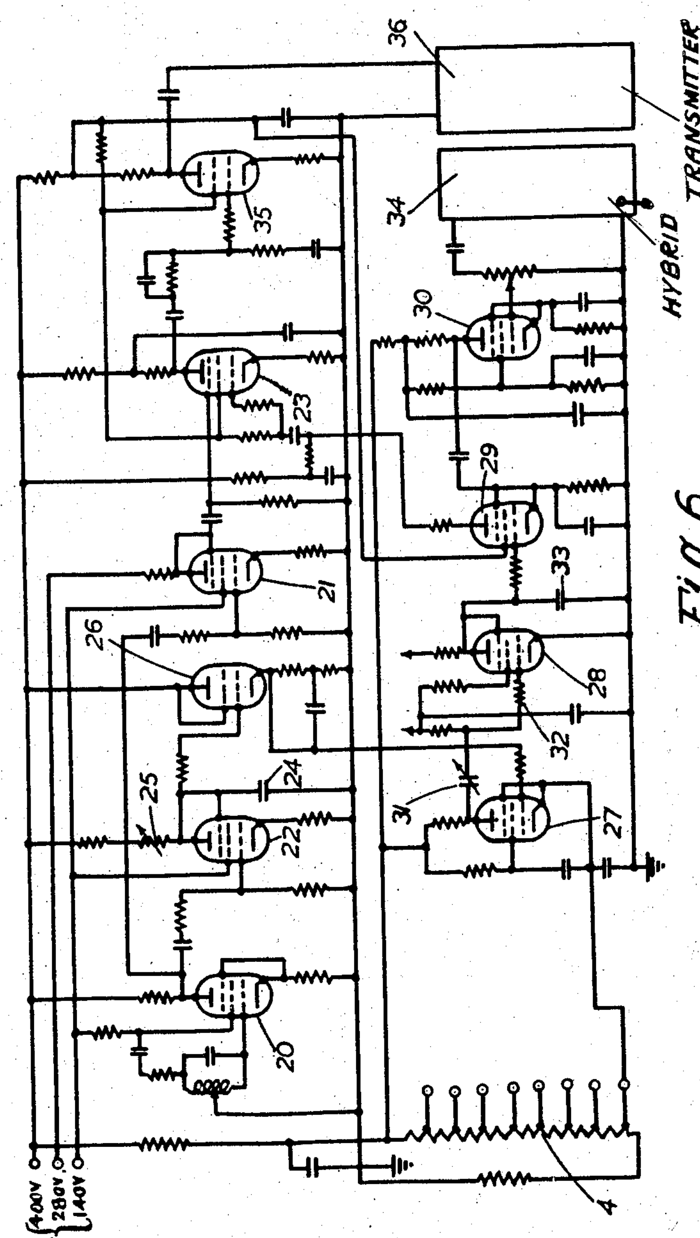

Fig. 6.

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MULTIPLEX PULSE MODULATION SYSTEM

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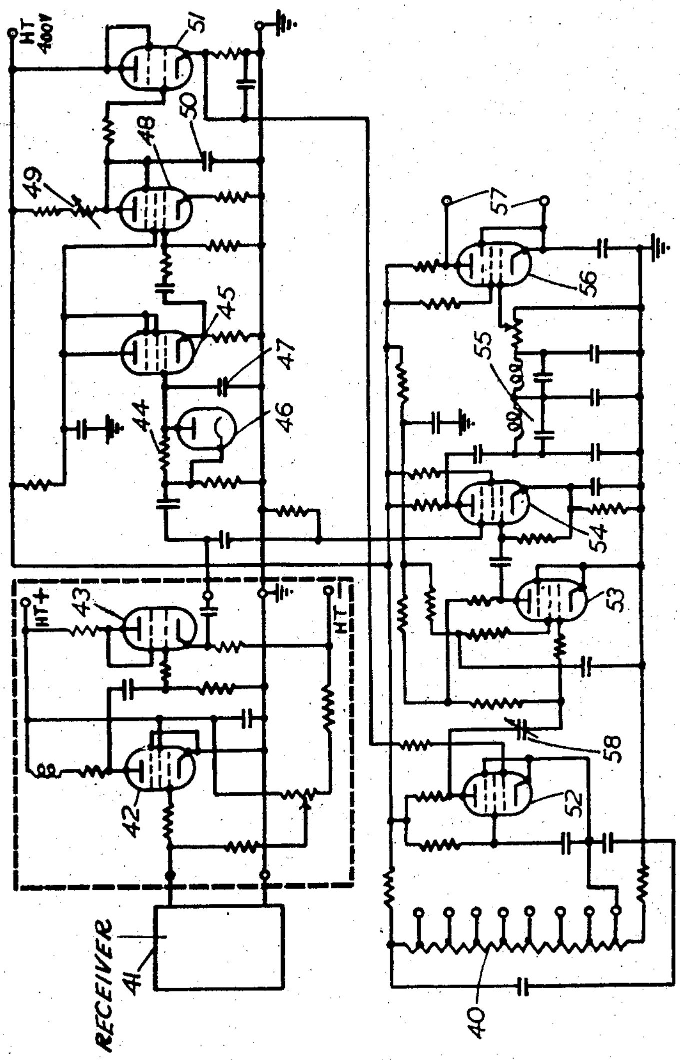

Fig. 8.

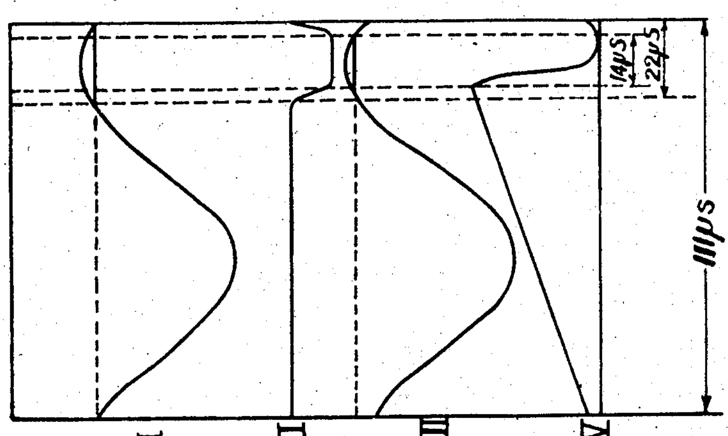

Fig. 7.

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UNITED STATES PATENT OFFICE

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MULTIPLEX PULSE MODULATION SYSTEM

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Application February 14, 1944, Serial No. 522,350
In Great Britain December 4, 1942

9 Claims. (Cl. 179—15)

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The present invention relates to electrical signalling systems of the type in which the signals, for example speech signals, are transmitted as fixed-amplitude pulses of radio frequency occurring at a fixed repetition frequency higher than the highest signal frequency it is desired to transmit and having a duration which varies in accordance with the instantaneous amplitude of the signals. Such pulses will be hereinafter referred to as variable-width pulses.

It is an object of the present invention to provide a multi-channel signalling system employing a single radio or cable link between transmitter and receiver in which this method of signal transmission is utilized.

A further object of the invention is to provide a multi-channel system in which the equipment necessary is lighter and smaller and is simpler and cheaper to construct than that of multichannel systems hitherto proposed, and in which the power available per channel is greater and the effect of noise or fading less than in previously proposed systems.

According to the present invention there is provided an electrical signalling system of the type described wherein signals from a number of channels are transmitted in the form of a train of variable-width pulses for each channel over a single link to a receiving point together with a train of "marker" pulses of a fixed width appreciably greater than the maximum width of the signal pulses, the pulses in each train having the same repetition frequency but being displaced in time relative to one another so that they can be interlaced for transmission over the single link, and wherein (at the receiving point) the marker pulses are separated from the signal pulses and are utilized to generate for each channel a train of "stroboscope" pulses of fixed width and of the same repetition frequency and timing as the signal pulses of that channel, the "stroboscope" pulses being utilized to effect the separation of the trains of signal pulses from one another.

According to a feature of the invention trains of pulses displaced in time relative to one another are generated by applying a saw-toothed wave of the desired repetition frequency to the control grids of a number of valves having an initial grid potential which is negative with respect to the cathode potential, the sudden drop in the anode voltage of each valve which occurs each time the rising grid potential approximately equals the cathode potential being utilized to develop a pulse, whereby each valve is used in developing a separate train of pulses, the relative

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timing of any two trains being determined by the relative values of the initial potential difference between the cathode and control grid of the two corresponding valves.

According to a further feature of the invention a particular train of variable width pulses is selected from a number of interlaced trains of variable width pulses by applying a negative potential to the control and suppressor grids of a pentode valve the interlaced trains of positive pulses being applied to one of these grids, the other grid having applied thereto a train of positive stroboscope pulses of the same frequency and timing as the train to be selected, and of a fixed width equal to the maximum width of the pulses to be selected, whereby the valve conducts only during the periods when a stroboscope pulse and a pulse of the train to be selected are simultaneously present.

The invention will now be described by way of example with reference to the accompanying drawings in which Figs. 1–4 illustrate in its simplest form a speech transmission system having eight speech channels and a single ultra-short wave radio link between the transmitter and receiver, whilst Figs. 5–8 are circuit diagrams and curves illustrating a preferred form of such a speech transmission system. In the drawings

Fig. 1 is an explanatory diagram showing the interlacing of the pulses;

Fig. 2 is a simple form of transmitter;

Fig. 3 is a series of curves showing the voltages at the electrodes of the valves of Fig. 2;

Fig. 4 is a schematic diagram of a simple form of receiver;

Fig. 5 shows the transmitted wave form of the preferred system;

Fig. 6 is a circuit diagram of a preferred form of pulse generating system;

Fig. 7 is a series of curves illustrating the generation of the marker pulses; and

Fig. 8 is a circuit diagram of the preferred receiving circuit.

In the simple arrangement to be described with reference to Figs. 1–4, the pulse train for each speech channel comprises pulses recurring at a fixed repetition frequency of approximately 9100 per second, the width of the pulses varying in accordance with the speech modulation in such a way that at a maximum depth of modulation they have a duration of 8 microseconds and at a minimum depth they have a duration of 2 microseconds. The pulse train for the "marker" channel, by means of which the fixed repetition frequency at which all the channels operate is conveyed to the receiver and there used to sort out the various speech channels, comprises pulses of fixed width recurring at the 9100 cycle repetition frequency the duration of each pulse being 14 microseconds. The manner in which the nine trains of pulses are interlaced is shown in Fig. 1. Considering one complete cycle of the repetition frequency, which has a duration of 109.5 microseconds, the first 14 microseconds are occupied by a marker pulse. This is followed by a gap of 3½ microseconds, and the succeeding period of 8 microseconds is available for a pulse of the first speech channel, the end of the pulse coinciding with the end of this period and the onset of the pulse varying in accordance with the speech modulation. This is followed by a second gap of 3½ microseconds and a second period of 8 microseconds for a pulse of second speech channel, and so on for all the eight speech channels. Thus any two consecutive pulses are separated by a minimum gap of 3½ microseconds. Clearly these figures are quoted by way of example only in order to clarify the description and are not essential to the performance of the invention. It is essential, however, that the duration of the marker pulse should be appreciably longer than the maximum duration of the speech pulses in order that it can be satisfactorily separated from them at the receiver. It is also essential that the maximum duration of the speech pulses should be limited to allow an adequate gap between consecutive pulses of maximum width and that the minimum duration of the speech pulses and of this gap should not be so short as to make necessary a prohibitively wide band pass for the system as a whole.

In the following description of the transmitting and receiving circuits and the manner in which they operate it will be assumed that time $t=0$ marks the beginning of each cycle of the repetition frequency and that time $t=109.5$ marks the end of each cycle, t being measured in microseconds.

The transmitter comprises eight series of valves for generating the speech channel pulses (one series being provided for each channel) and a ninth series for generating the marker pulses. In Fig. 2, the ninth series is indicated by the references V1A and V2A, whilst the first two only of the speech channel pulse generators are shown (V1B—V3B and V1C—V3C). A common output valve V4 is provided for all the nine series. A saw-toothed voltage from the generator 1 is applied to the control grid of the first valve of each series, the period of this voltage being that of the desired repetition frequency (curve A, Fig. 3). The first valve in each series is normally cut-off so that its anode voltage will remain at a high value from $t=0$ until the rising voltage on its grid approximately equals its cathode voltage. The valve then conducts and the anode voltage drops to a lower value at which it remains until the beginning of the next cycle, at which point it suddenly rises to the cut-off value again. This sudden rise in the anode voltage of the first valve V1A of the marker channel pulse generator is utilized for developing the marker pulses (curve B, Fig. 3). For this purpose, the first valve V1A is connected through a resistance-condenser network 2, 3 to the control grid of a second valve V2A, the time constant of this network being so chosen that this control grid rises to a positive value at $t=0$ and is maintained at this value until $t=14$, when it reverts to its normal negative value (curve C, Fig. 3). Negative pulses, or pulses of reduced anode voltage, lasting from $t=0$ to $t=14$ thus appear in the anode circuit of this second valve (curve D, Fig. 3), and these are transferred to the common output valve V4, appearing as positive pulses, or pulses of increased anode voltage, in its anode circuit (curve P, Fig. 3).

In generating the speech pulses, the sudden drop in anode voltage which occurs when the first valve V1B, V1C, etc., of each pulse generator suddenly conducts is utilized. The time at which this occurs obviously depends upon the cathode potential, and in order to achieve the desired interlacing of the eight trains of pulses, the cathode of each of the first valves is connected to a different tapping on a potentiometer 4, the cathode for the first generator V1B being the least and that for the eighth, the most positive. The pulses for the first speech channel are generated as follows: The cathode positive potential of the first valve V1B is held at such a value that the rising grid potential approximately equals it at $t=17.5$, and the sudden drop in anode voltage therefore occurs at this point (curve E, Fig. 3). The first valve is connected through a condenser-resistance network 5, 6 to the control grid of a second valve V2B, this grid being normally held slightly positive. The time constant of this network is such that the grid of the second valve drops to a negative value at $t=17.5$ and is maintained at this value until $t=25.5$, when it returns to its normal positive value (curve G, Fig. 3). The anode potential of this second valve is normally at a low potential except during this negative pulse on the grid, so that a condenser 7 connected between the anode and earth begins to charge at the beginning of the grid pulse and is suddenly discharged at the end of it. A short saw-toothed pulse beginning at $t=17.5$ and ending at $t=25.5$ is thus generated by the second valve (curve I, Fig. 3). This is applied to the control grid of a modulator valve V3B having a transformer 8 in its cathode circuit to the input of which the speech potentials from channel No. 1 are applied. The short saw-toothed pulse of voltage applied to the grid is opposed by a steady positive voltage on the cathode which has a value such that, in the absence of speech modulation, the grid is driven positive for 5 microseconds from $t=20.5$ to $t=25.5$. Application of speech potentials to the cathode causes the grid potential to swing in accordance therewith so that the grid is driven positive for times varying from 2 to 8 microseconds, that is from between $t=23.5$ and $t=17.5$ to $t=25.5$ microseconds (curve K, Fig. 3). The anode of the modulator valve is held positive except during this period when the grid is driven positive, on which occasion it is driven negative due to the surge of anode current lasting from 2–8 microseconds. The resulting pulses of anode current vary in width from cycle to cycle sinusoidally in accordance with the speech modulation between the limits $t=23.5$ and $t=17.5$ for the commencement of the pulse and $t=25.5$ for the end of the pulse (curve M, Fig. 3).

The pulses for the second channel are generated in exactly the same way (curve F, H, J, L and N, Fig. 3) except that the cathode potential of the first valve is chosen at a slightly higher positive value so that the sudden drop in the anode current occurs at $t=29$. This results in pulses commencing from between $t=35$ and $t=29$ and ending at $t=37$. The pulses for the remaining channels are successively delayed by equal amounts by appropriate choice of the cathode potentials for the first valve in each case.

The anode circuits of all the eight modulator valves are connected to the control grid of the common output valve, so that the negative pulses generated by each of these valves are applied to the grid one after the other (curve O, Fig. 3). Corresponding positive pulses for all the eight channels, interlaced in the required manner, thus appear in the anode circuit of the output valve (curve P, Fig. 3). The output of this valve is used to modulate an ultra-short wave radio sender 9.

The transmitted signal is received on a normal receiver 10 (Fig. 4) of the supersonic heterodyne type having a pass-band wide enough to handle the narrowest pulses which may occur. The output of the second detector of the receiver will consist of the series of interlaced pulses already described. The first step is to reproduce at the receiving point the repetition frequency at which all the channels operate. This is done by applying a portion of the output of the second detector to the grid of a valve 11, whose function is to convert the positive pulses occurring in this output into negative pulses. If the output already consists of negative pulses this valve is not required. The negative pulses are applied to the control grid of a valve 12, the cathode of which is held slightly negative, so that the valve passes anode current of saturation value except during the persistence of the pulses. A condenser 13 connected between the anode of this valve and earth will thus charge during the persistence of each pulse and will discharge suddenly at the end of the pulse: the voltage to which the condenser is charged will depend upon the length of the pulse. As the length of the marker pulse exceeds that of any other by at least 6 microseconds the condenser voltage will reach a greater positive value at the end of the period of application of a marker pulse to the grid of the valve than at the end of the period of application of any speech pulse. The voltages developed across the condenser are applied to the control grid of a second valve 14, the cathode potential of which is held at such a positive value that only the voltages produced by the marker pulses can cause any passage of anode current. The condenser voltages produced by the speech pulses are insufficient to swing the grid positive. Consequently, pulses corresponding to the marker pulses only appear in the anode circuit of the second valve; these occur at the desired repetition frequency and are used to lock an oscillator 15 generating a saw-toothed wave substantially identical with that employed at the transmitter. By means of a slightly modified version of the process already described for the transmitter, this saw-toothed wave is utilized to generate eight trains of positive pulses, which may be termed "stroboscope" pulses. These are unmodulated, having a fixed duration of 8 microseconds, and the pulses in each train are in step with those in the corresponding train of speech pulses. Thus the stroboscope pulses in the first train last from $t=17.5$ to $t=25.5$ microseconds and are thus in step with the pulses of the first speech channel; those in the second train last from $t=29$ to $t=37$ microseconds and are thus in step with the pulses of the second speech channel; and so on. The stroboscope pulse generators are indicated diagrammatically at G1–G8 in Fig. 4. Each comprises a pair of valves connected in the same way as the first two valves of each speech channel pulse generator and operating in the manner already described and illustrated in curves E–H of Fig. 3. The required pulses appear in the anode circuit of the second valve.

The other portion of the output from the second detector of the receiver is fed to the control grids of eight pentode valves P1–P8 connected in parallel. To the suppressor grid of the first of these valves P1, the potential of which is normally negative, are applied the first train of stroboscope pulses from the generator G1. The valve passes current only during the periods when the stroboscope pulses and the speech pulses of channel 1 are simultaneously present and consequently there will appear in the output circuit only the pulses of the first speech channel. Similarly, the second train of stroboscope pulses from G2 are applied to the suppressor grid of the second pentode valve P2, so that there will appear in the output circuit of this valve only the pulses of the second speech channel, and so on. Thus the pulses of the eight speech channels have been sorted out from one another. The eight pentode valves are connected to output circuits O1–O8 which contain any known or suitable arrangement for integrating the variable width pulses and thus converting them into oscillations of speech frequency, and also suitable terminal equipment for feeding these oscillations into the lines.

A preferred form of apparatus will now be described with reference to Figs. 5–8. The waveform of the transmitted signal is illustrated diagrammatically in Fig. 5. From this it is clear that the marker pulse has a duration of 22 microseconds and occurs at the end of the eight speech channels; i. e. the end of the marker pulse instead of its beginning marks the datum point in time. Each speech channel pulse has a duration of 4 microseconds when unmodulated; when modulated by the speech currents its duration can vary between 1 and 7 microseconds. The leading edge of each speech channel pulse is fixed and the position of the rear edge varies with the modulation, as in the system previously described. The duration of the gaps separating the various pulses is indicated in the figure and it is clear that any pulse will be separated from its neighbour by a gap of at least 3 microseconds duration. The duration of each cycle is 111 microseconds corresponding to a repetition frequency of 9100 cycles per second.

The pulse generating circuits are shown in Fig. 6. In order to simplify the drawing only one of the eight identical series of valves for generating the speech channel pulses is shown. In general, the operation of these circuits is similar to that of the circuits already described with reference to Figs. 2 and 3 the only important difference being the method of generating the marker pulses. The 9100 cycle repetition frequency is generated by the sine wave oscillator 20, the sinusoidal output of which is applied to the control grid of the marker pulse generator 21, and also to the control grid of the saw-tooth voltage generator 22. As illustrated in curve I of Fig. 7 the grid of the valve 21 is negatively biased so that only the peak of the positive half-cycle of the applied voltage is effective in removing the cut-off bias and rendering the valve conductive, the duration of the conductive period being 22 microseconds. Consequently a negative pulse of 22 microseconds duration appears in the anode circuit (curve II, Fig. 7) and this is applied to the outer grid of the common mixer valve 23. A similar action occurs in saw-toothed voltage generator 22, the duration of the conductive period being limited in this case to 14 microseconds (curve III, Fig. 7). During this period the condenser 24 discharges, producing a voltage flyback, and then charges through the resistance 25, the resulting saw-toothed voltage in the anode circuit being indicated in curve IV of Fig. 7. This voltage is passed through an output valve 26 connected as a cathode follower to the control grid of the valve 27, which together with the valves 28, 29 and 30 constitute the pulse generator for the first speech channel. The operation of this is substantially similar to that already described with reference to Figs. 2 and 3 and need only be outlined briefly. As before, the timing of the pulses is determined by an appropriate choice of the cathode potential of the valve 27, this being fixed by connecting the cathode to the first tapping point on the potentiometer 4. The negative impulses which occur in the anode circuit of the valve 27 each time it conducts are applied through the variable condenser 31 and resistance 32 to the control grid of the valve 28. The duration of the negative impulse applied to this control grid can be varied by varying the capacity of the condenser 31, and in this case is set at approximately 7 microseconds. During this period of 7 microseconds the valve 28 is cut off, the condenser 33 charges and then suddenly discharges at the end of the period thus producing in the anode circuit of the valve 28, a positive pulse of saw-toothed form lasting for 7 microseconds. This pulse is applied to the control grid of the modulator valve 29 and drives the grid positive with respect to the cathode for a period the length of which depends upon the cathode potential. In the absence of a modulating voltage the cathode potential is such that the grid is driven positive for a period of 4 microseconds. The speech currents for channel I are fed from the incoming line into a conventional hybrid circuit 34, and after amplification by the valve 30 are injected into the cathode circuit of the valve 29 to vary the cathode potential in accordance with the speech current amplitude. As a result the grid of valve 29 is driven positive for a period varying between 1 and 7 microseconds according to the speech amplitude, and corresponding negative pulses appear in the anode circuit of valve 29. These are fed to the control grid of the common mixer valve 23, together with the outputs of the similar pulse generators for the seven remaining channels. The control grids of the first valves of these generators are all fed with the saw-toothed voltage from the output valve 26 whilst their cathodes are connected to appropriate taps on the potentiometer 4. The output of the mixer valve 23 will then consist of a series of positive pulses interlaced in the manner shown in Fig. 5, and after amplification by the valve 35, this output is employed to modulate the amplitude of an ultra-high frequency carrier generated by the transmitter 36.

The separating and demodulating circuits are shown in Fig. 8. The pulse modulated carrier is received by a supersonic-heterodyne receiver 41, the output from the second detector being applied to the control grid of a limiting valve 42. The negative bias applied to this grid results in the lower portion of the pulses being cut-off, whilst the load in the anode circuit of the valve sets an upper cut-off limit. As a result only a thin horizontal "slice" of the pulses is transmitted to the control grid of the cathode follower stage 43. The output of this stage is fed through the resistance 44 to the control grid of the valve 45. During each pulse the diode 46 shunting the resistance 44 is cut off, and the small condenser 47 is charged through the resistance 44 until the diode suddenly conducts at the end of the pulse. The voltage on the grid of the valve 45 will thus increase during each pulse and then suddenly fall at the end of the pulse, and since the duration of a marker pulse greatly exceeds that of the speech channel pulses, it will reach a much higher value at the end of each marker pulse. Corresponding voltage changes are fed from the cathode circuit of the valve 45 to the control grid of a saw-toothed voltage generator 48 having the usual charging resistance 49 in its anode circuit and condenser 50 connected across it. The voltage changes due to the speech channel pulses are insufficient to swing the control grid positive and consequently the condenser 50 charges until the arrival of a marker pulse produces a voltage change of sufficient amplitude to render the valve 48 conductive. There is thus produced in the anode circuit of the valve 48 a saw-toothed voltage which is synchronous with that produced by the valve 22 of Fig. 5, and which starts increasing at the end of a marker pulse and flies back to its original value during the marker pulse. This saw-toothed voltage is fed via the cathode-follower stage 51 to the control grid of the valve 52. This valve together with the valve 53 constitute the generator of the stroboscope pulses for the first channel. They operate in manner substantially similar to the valves 27 and 28 of Fig. 6, except that as the valve 53 has no condenser corresponding to condenser 33 of Fig. 5 connected across it, the positive stroboscope pulses in its anode circuit will be square shaped instead of saw-toothed. The timing of these pulses is arranged to coincide with that of the speech pulses of the first channel by connecting the cathode of valve 52 to the appropriate tap on the potentiometer 40, whilst the width of the pulses is fixed at approximately 9 microseconds by choosing an appropriate setting for the condenser 58. The stroboscope pulses are applied to the inner grid and the signal pulses from the cathode circuit of valve 43 are applied to the outer grid of the separator valve 54. This operates in the manner already described in connection with Fig. 4, and only the speech pulses of the first channel appear in its anode circuit. These are applied to an integrating circuit comprising a low-pass filter 55 and an output amplifier 56 which act is known manner to produce an output voltage varying in amplitude in accordance with the original speech current. This is applied via terminals 57 to the hybrid circuit 34 and from thence to the outgoing line. Series of valves, each similar to the series 52–56, are employed for each of the remaining seven speech channels, the timing of the stroboscope pulses for each channel being arranged to coincide with the speech pulses in that channel by connecting the cathode of the first valve to the appropriate tap on the potentiometer 40.

As mentioned above, the most important difference between the arrangement shown in Figs. 6 and 8 and the system described with reference to Figs. 1–4 resides in the method of generating the marker pulse. With this method more satisfactory stability of the synchronization in the receiver can be obtained.

Inspection of the pulse widths, the spaces between them, and the position of the stroboscope pulses relative to their respective speech channel pulses can be readily carried out by means of cathode ray oscilloscopes at the transmitter and receiver. The saw-toothed wave employed in the generation of the pulses can be utilized to provide a suitable time base, the pulses being applied to the signal plates of the oscilloscopes.

For secret signalling a system of enciphering and deciphering can be employed in which the various potentials applied to the cathode of the first valves of the pulse generators are interlaced in a random manner in order to scramble the channels, the reverse process being correspondingly employed at the receiver. For this purpose the repetition frequency can be divided to produce a suitable operating frequency for synchronous motors at the transmitter and receiver for operating the enciphering and deciphering switches.

The system according to the invention has the following advantages as compared with multichannel systems depending on the use of tuned filters. The equipment is much lighter and smaller and requires less skill in construction, since, in the main, it uses valves with simpler condenser-resistance coupling networks. Also the circuit constants for each channel are identical, selection of a channel being determined simply by the adjustment of a potentiometer. Furthermore, the power available is (approximately) inversely proportional to the number of channels instead of to the square of the number of channels. Finally, by using the technique of pulsed transmission it is possible, by using suitable limiters, to receive only thin horizontal "slice" of all the pulses, thus eliminating or reducing noise and the effects of any fading which may occur. On the other hand a band pass of several megacycles per second is required by the system which is therefore applicable only to radio links operating on very short wavelengths or to routes using high quality cable.

We claim:

1. A method of transmitting electrical signals from a number of channels over a single link to a receiving point and there separating and distributing them to an equal number of channels, which comprises the steps of generating at the transmitting point a separate train of voltage pulses for each channel, the repetition frequency of the pulses being the same for all the trains but the timing of the pulses in each train being different, varying the duration of the pulses in each train in accordance with variations in amplitude of the signal from the corresponding channel, generating a train of marker pulses having a repetition frequency equal to that of the channel pulses but an appreciably longer duration, interlacing the various trains of pulses, utilizing the interlaced pulses to modulate a radio frequency wave, transmitting the radio frequency wave to a receiving point, demodulating the radio frequency wave to reproduce the interlaced pulses at the receiving point, separating the marker pulses from the interlaced channel pulses, utilizing the marker pulses to control the generation of a separate train of selecting impulses of fixed duration for each channel, the timing of the selecting impulses in each train being the same as that of the pulses in the corresponding train, combining in a separate circuit for each channel the interlaced pulses with the selecting impulses of one of the trains, utilizing the selecting impulses in each of said circuits to select the pulses in step therewith and to suppress the remainder, and converting the selected pulses from each circuit into a signal of varying amplitude.

2. An electrical signalling system comprising a plurality of incoming signal channels, a signal pulse generator for each channel, means for generating a periodically recurring triggering voltage arranged to trigger each generator in turn at a fixed repetition frequency, a device associated with each generator for varying the duration of the pulses in accordance with the amplitude of the signal in the corresponding channel, a common output circuit in which all the trains of pulses from all said generators are interlaced, radio transmitting and receiving circuits for transmitting the interlaced pulses over a single link and reproducing them at a receiving point, a selecting impulse generator for each channel at said receiving point, means for generating a periodically recurring triggering voltage arranged to trigger each selecting impulse generator in synchronism with the corresponding signal pulse generator, a selecting circuit for each channel fed with the interlaced signal pulses and with the output of one of said selecting impulse generators and arranged to pass one only of the interlaced trains of signal pulses, and an outgoing channel from each selecting circuit.

3. An electrical signalling system comprising a plurality of incoming signal channels, a signal pulse generator for each channel, means for generating a periodically recurring triggering voltage arranged to trigger each generator in turn at a fixed repetition frequency, a device associated with each generator for varying the duration of the pulses in accordance with the amplitude of the signal in the corresponding channel, a generator for producing marker pulses of longer duration than the signal pulses at said fixed repetition frequency, a common output circuit in which all the trains of pulses from all said generators are interlaced, radio transmitting and receiving circuits for transmitting the interlaced pulses over a single link and reproducing them at a receiving point, a discriminating circuit for separating said marker pulses from the interlaced channel pulses, at said receiving point, a selecting impulse generator for each channel, means under the control of the separated marker pulses for generating a periodically recurring triggering voltage arranged to trigger each generator in synchronism with the corresponding signal pulse generator, a selecting circuit for each channel fed with the interlaced signal pulses and with the output of one of said selecting impulse generators and arranged to pass one only of the interlaced trains of signal pulses, and an outgoing channel from each selecting circuit.

4. An electrical signalling system according to claim 2 wherein there is provided a generator for developing a saw-toothed voltage recurring at the fixed repetition frequency and wherein each signal pulse generator includes a thermionic valve having its cathode potential fixed at a voltage which is positive relative to its grid potential, this voltage being different for each generator, means for applying the saw-toothed voltage to the grid of all the thermionic valves to cause each one to conduct in turn when its changing grid potential equals its cathode potential, and means for utilizing the sudden conduction to develop a pulse.

5. An electrical signalling system according to claim 2 wherein the device for varying the duration of the signal pulses from each generator comprises a first thermionic valve having a negative bias on its control grid and a condenser connected in shunt therewith, a connection for applying the signal pulses to the control grid of

said first valve, whereby a short saw-toothed pulse of positive voltage is produced in its anode circuit, a second thermionic valve, means for varying the cathode potential of said second valve in accordance with the amplitude of the signal, and a connection for applying to the control grid of said second valve the saw-tooth pulse produced in the anode circuit of said first valve.

6. An electrical signalling system according to claim 2 wherein each selecting circuit comprises a thermionic valve having a control grid and a suppressor grid, each negatively biased, means for applying the interlaced signal pulses of positive voltage to one grid and the positive selecting impulses from one generator to the other grid, whereby the valve conducts only when a selecting impulse and a signal pulse are simultaneously present.

7. An electrical signalling system according to claim 3 wherein the discriminating circuit includes a condenser arranged to be charged during each incoming pulse to a potential dependent upon the duration of the pulse and to be discharged at the end of the pulse, a thermionic valve having a negatively biased control grid, and a connection for applying the condenser voltage to the control grid of said thermionic valve, which thereby conducts to a greater extent during a marker pulse than during a signal pulse.

8. An electrical signalling system comprising a plurality of incoming signal channels, a signal pulse generator for each channel, a marker pulse generator, means for generating a first saw-toothed voltage wave having a fixed repetition frequency, a thermionic valve in each generator responsive to said saw-toothed voltage wave and arranged to conduct at a certain point along the wave which is different for each generator, means in each generator for utilizing the conduction to develop a pulse, means in each signal pulse generator for varying the duration of the pulse in accordance with the instantaneous amplitude of the corresponding signal, an output circuit in which the pulses from all the generators are interlaced, radio transmitting and receiving circuits for transmitting the interlaced pulses over a single link and reproducing them at a receiving point, a discriminating circuit for separating the marker pulses from the interlaced signal pulses at said receiving point, means under the control of the separated marker pulses for generating a second saw-toothed voltage wave synchronous

with the first, a selecting impulse generator for each channel responsive to said second saw-toothed wave and operating in the same manner as the corresponding signal pulse generator to develop impulses of fixed duration in synchronism with the corresponding signal pulses, a selecting circuit for each channel fed with the interlaced pulses and with the selecting impulses from one of said generators and arranged to pass one only of the interlaced trains of pulses, and an outgoing channel for each selecting circuit.

9. An electrical signalling system comprising a plurality of incoming signal channels, a signal pulse generator for each channel, a sine wave oscillator, means controlled by said oscillator for developing a first saw-toothed voltage wave, a marker pulse generator controlled by said oscillator and arranged to develop a pulse during the flyback of said saw-toothed wave, a thermionic valve in each signal pulse generator responsive to said saw-toothed voltage wave and arranged to conduct at a certain point along the wave which is different for each generator, means in each signal pulse generator for utilizing the conduction to develop a pulse, means in each signal pulse generator for varying the duration of the pulse in accordance with the instantaneous amplitude of the corresponding signal, an output circuit in which the pulses from all the generators are interlaced, radio transmitting and receiving circuits for transmitting the interlaced pulses over a single link and reproducing them at a receiving point, a discriminating circuit for separating the marker pulses from the interlaced signal pulses at said receiving point, means under the control of the separated marker pulses for generating a second saw-toothed voltage wave synchronous with the first, a selecting impulse generator for each channel responsive to said second saw-toothed wave and operating in the same manner as the corresponding signal pulse generator to develop impulses of fixed duration in synchronism with the corresponding signal pulses, a selecting circuit for each channel fed with the interlaced pulses and with the selecting impulses from one of said generators and arranged to pass one only of the interlaced trains of pulses, and an outgoing channel for each selecting circuit.

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