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DEVICE FOR CONVERTING A SIGNAL OF VARIABLE AMPLITUDE INTO PULSES OF CONSTANT FREQUENCY AND VARIABLE DURATION

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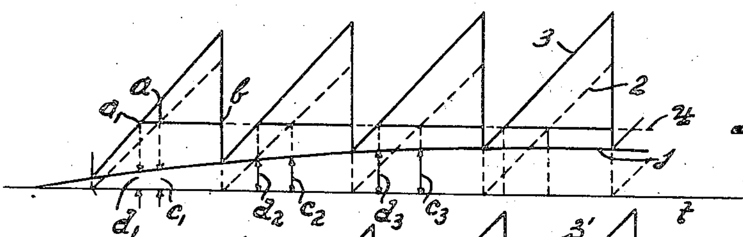

Fig. 1

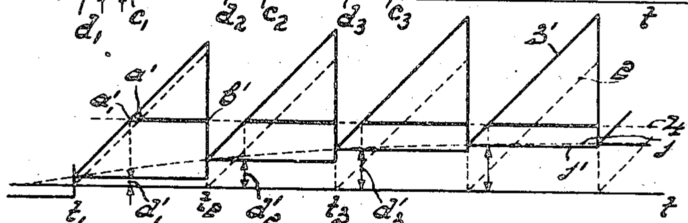

Fig. 2

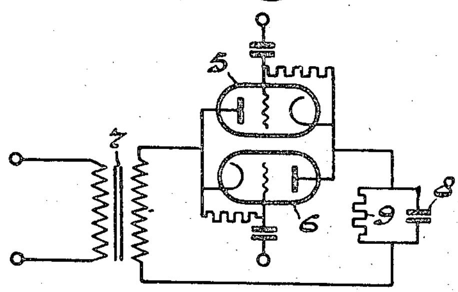

Fig. 3

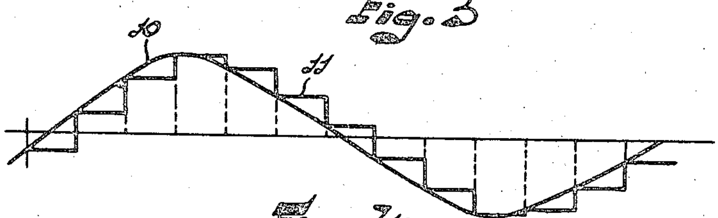

Fig. 4

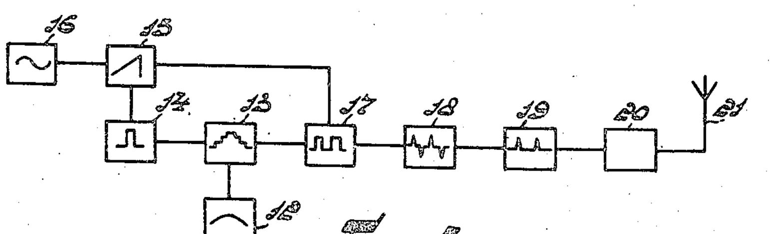

Fig. 5

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DEVICE FOR CONVERTING A SIGNAL OF VARIABLE AMPLITUDE INTO PULSES OF CONSTANT FREQUENCY AND VARIABLE DURATION

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13 Claims. (Cl. 332—15)

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For the transmission of signals by means of a modulated carrier-wave it is known to utilise time modulation and impulse phase-modulation. In the case of time modulation the carrier-wave is modulated by pulses of constant frequency, the duration of which is dependent on the instantaneous value of the amplitude of the signal to be transmitted. With impulse phase-modulation the duration and the mean frequency are constant but there is variation in the time difference between the moment at which the pulses occur and the moment at which in the unmodulated condition they would occur with the instantaneous value of the amplitude of the signal to be transmitted. The duration of the pulses is then small with respect to their mutual distance.

With each method of modulation the instantaneous value of the amplitude of the signal to be transmitted at isochronous moments must be converted into time.

It is known to convert the instantaneous value of the amplitude of a signal to be transmitted into pulses of constant frequency whose duration is proportional to the instantaneous amplitude by causing the signal to be transmitted, jointly with a sawtooth voltage of the desired impulse frequency, to pass through a threshold device. It is possible, for example, to supply the two voltages to the grid of a tube which is only conductive if the voltage set up at the grid exceeds a given threshold value.

To make this better understood, Figure 1 of the drawing shows as a function of time a part **1** of a signal voltage which is to be converted into pulses. The resulting voltage obtained on summation of the signal voltage and a sawtooth voltage **2** of the desired impulse frequency is represented by the curve **3**. The frequency of the sawtooth voltage is high with respect to that of the signal voltage. The amplitude of the sawtooth voltage is equal to, or higher than the maximum amplitude of the signal voltage.

Assuming the threshold voltage to be equal to the amplitude of the sawtooth voltage and represented by a horizontal line **4**, then in the absence of a signal to be transmitted the threshold voltage is passed at points a and b located respectively at the centres of the two flanks of the sawtooth voltage. In the presence of the signal **1** to be transmitted the threshold voltage line **4** is passed during periods of time occurring between the points a_1 and b. A discharge tube circuit having a threshold value to which the resulting voltage **3** is supplied is thus conductive

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during those time periods which are shown in horizontal thick lines in the drawing so that a pulsatory voltage occurs in the output circuit, the duration of the pulses being dependent on the instantaneous value of the amplitude of the signal voltage **1**.

This known method of converting a voltage of variable amplitude into pulses of constant frequency and of a duration dependent on the instantaneous value of the amplitude of the variable voltage may, however, involve distortion, more particularly in the conversion of frequencies of the order of magnitude of the impulse frequency.

The present invention is based on the recognition that this distortion is caused by the fact that it is not the instantaneous values of the amplitude of the signal c_1, c_2, c_3 to be transmitted, which occur at isochronous moments, that become manifest in the duration of the pulses, but the instantaneous values d_1, d_2, d_3, the time intervals therebetween being dependent on the shape of the signal curve, so that there is no linear relation between the instantaneous values of the amplitude at isochronous moments and the duration of the pulses.

The distortion increases as the amplitude of the signal curve varies more strongly during the periodic time of the sawtooth voltage, so that it increases with frequency.

According to the invention, the said drawback is obviated by converting the signal of variable amplitude into a stepped wave, the instantaneous amplitude of which, at isochronous moments steps to the instantaneous value of the amplitude of the signal which occurs at these moments, said moments recurring at a rate which corresponds to the desired impulse frequency, whereupon this stepped wave is converted into impulses having the desired time character.

The stepped wave is preferably supplied in series with a sawtooth voltage of the desired impulse frequency to the grid of a tube having a threshold value.

Figure 2 of the drawing shows as a function of time a portion **1** of the signal voltage to be transmitted while the stepped wave, into which the signal is converted, is represented by the curve **1'**. The instantaneous amplitude of the wave at the time t_1 is equal to the instantaneous value of the amplitude of the signal at that moment and steps at the moments t_2, t_3 etc. to the instantaneous value of the amplitude of the signal **1** which occurs at the said moments. The rate at which the wave 1' steps is equal to the desired impulse frequency.

The resulting voltage obtained on summation of the stepped wave 1' and a sawtooth voltage 2 of the desired impulse frequency is represented by the curve 3'.

The threshold voltage value line 4 is passed by this voltage at a moment at which the difference between the amplitude of the sawtooth voltage 2 when unmixed with the stepped wave and its amplitude at that moment is equal to the instantaneous amplitudes d'_1, d'_2 and d'_3 respectively of the voltage 1', which difference is proportional to the time difference between the points a' and a'_1. Since, however, the instantaneous amplitudes d'_1, d'_2 and d'_3 respectively of the voltage 1' is equal to the instantaneous value of the amplitude of the signal to be transmitted at the times t_1, t_2 and t_3 respectively, the time difference between the points a'_1 and a' is proportional to the amplitude of the signal to be transmitted at the times t_1, t_2 and t_3 respectively.

The variation in the duration of the pulses, which is brought about by the signal to be transmitted, is therefore proportional to the instantaneous value of the amplitude of the signal to be transmitted at isochronous moments (t_1, t_2, t_3, . . .), due to which the distortion occurring in known devices is suppressed.

The stepping action preferably takes place during the flyback periods of the sawtooth voltage, as shown in Figure 2, so that the whole duration between the pulses is available for the modulation of the duration of the pulses $a'b'$, which occur in the absence of the signal. If the stepping action takes place during the inclined flank of the sawtooth voltage, only a portion of the said duration is available for the modulation and a modulation depth smaller than 100% is unavoidable.

In one form of construction the transformation of the signal of variable amplitude into a stepped wave is effected by supplying this signal to two charging circuits having a common condenser and allowing the passage of currents through the condenser in opposite directions, the circuits comprising non-linear elements controlled by short impulses of the desired impulse frequency in such manner that, according to the direction of variation of the instantaneous value of the amplitude of the signal to be transmitted, one charging circuit or the other is operative during the pulse.

Figure 3 is a diagrammatic view of this form of construction. The non-linear elements in the two charging circuits are constituted by discharge tubes 5 and 6 which are connected in such manner that the cathode of one tube is connected to the anode of the other tube and inversely. An input impedance common to the two charging circuits is constituted by a transformer 7 which has supplied to it the voltage of continuously vary amplitude that is to be converted. An output impedance, common to the two circuits, is constituted by a parallel-connected condenser 8 and resistance 9. A pulsatory voltage constituted by short pulses of a periodicity corresponding with the desired stepping rate is supplied to the grids of the two tubes in such manner that during each pulse a positive grid voltage with respect to the associated cathode is supplied to the tubes simultaneously.

By the correct choice of its value, the condenser 8 during each pulse of the voltage supplied to the tube 5 and 6 is quickly charged

through one of the tubes until the voltage of the condenser has a value equal to the instantaneous value, during the pulse, of the amplitude of the voltage supplied to the transformer 7. The condenser 8 retains this voltage during the time between two pulses provided that the discharge time of the condenser has a high value with respect to the periodic time of the impulse frequency. As long as the instantaneous value of the amplitude of the supplied voltage in the positive sense is greater than the voltage set up at the condenser 8, the latter is charged through the tube 5. If the instantaneous value falls below the voltage of the condenser 8, then the latter is discharged through the tube 6 until the obtainment of the instantaneous value. During the other half wave of the supplied voltage the condenser 8 is charged through the tube 5 or discharged through the tube 6. Consequently, the voltage of condenser 8 will assume a stepped form as shown in Figure 4, in which 10 and 11 denote respectively the voltage of variable amplitude supplied to the transformer 7 and the stepped output voltage set up at the condenser 8. The variation of the output voltage is such that its value is determined at any moment by the instantaneous value of the amplitude of the signal voltage during the preceding pulse. The rate at which the voltage steps is equal to that of the pulses supplied to the grids of the tubes 5 and 6.

If the stepped voltage set up at the condenser 8 is supplied, in series with a sawtooth voltage of the impulse frequency, to the grid of a tube having a threshold value, pulses are produced in the anode circuit of a duration which is always determined by the instantaneous value of the amplitude of the initial signal voltage at isochronous moments.

Figure 5 shows a form of a transmitting arrangement for impulse phase-modulation in which use is made of a device according to the invention.

In this arrangement the signal voltage of variable amplitudes which is to be transmitted and which originates from a source of supply 12 is supplied to a device 13 according to the invention for the conversion of a voltage of continuously varying amplitude into a stepped voltage. To the device 13 are supplied, in addition, voltage impulses for periodically making the rectifying tubes conductive. The said voltage impulses whose frequency is equal to the desired mean frequency of the phase-modulated impulses which are to be transmitted originate from a source of supply 14 and are derived from a sawtooth oscillation of the same frequency which is generated by a sawtooth oscillator 15. The frequency of the voltage generated by the sawtooth oscillator 15 is stabilized by an oscillator 16 which generates a sinusoidal wave of constant frequency.

The stepped output voltage of the device 13 and the sawtooth voltage of the oscillator 15 are jointly supplied to a device 17 having a threshold value and which converts the supplied signal voltage into impulses of constant frequency, the duration of which is dependent on the instantaneous value of the amplitude of the signal voltage of source 12 at isochronous moments.

These impulses are differentiated in a device 18 so that in the output circuit of the device 17 we obtain for each impulse two short impulses of opposite polarity indicating respectively the beginning and the end of the initial pulse. In a device 19 the short impulses indicating the end of the pulses in the output circuit of the device 17 are cut off. Subsequently, the resulting short impulses, the mutual distance of which varies with the instantaneous value of the amplitude of the signal to be transmitted, are modulated on a carrier-wave in a transmitter 20, the modulated carrier-wave being emitted by an aerial 21.

What I claim is:

1. Apparatus for converting an amplitude-modulated signal into pulses of constant periodicity, the duration of said pulses being dependent on the instantaneous amplitude of said signal, said apparatus comprising means to generate a stepped wave the amplitude of which at isochronous moments steps to a value proportional to the instantaneous amplitude of said signal at said moments, said moments recurring at a rate corresponding to said constant periodicity, and means to convert each step of said wave into a pulse whose duration is proportional to the amplitude thereof.

2. Apparatus for converting an amplitude-modulated signal into pulses of constant periodicity, the duration of said pulses being dependent on the instantaneous amplitude of said signal, said apparatus comprising means to generate a stepped wave the amplitude of which at isochronous moments steps to a value proportional to the instantaneous amplitude of said signal at said moments, said moments recurring at a rate corresponding to said constant periodicity, means to generate a sawtooth wave having a frequency corresponding to said constant periodicity, means to combine said stepped wave and said sawtooth wave, and means to derive from the combined wave pulses whose duration is proportional to the instantaneous amplitude of said stepped wave.

3. Apparatus as set forth in claim 2 further characterized by the fact that the flyback periods of said sawtooth wave are coincident with said isochronous moments.

4. Apparatus for converting an amplitude-modulated signal into pulses of constant periodicity, the duration of said pulses being dependent on the instantaneous amplitude of said signal, said apparatus comprising means to generate a stepped wave the amplitude of which at isochronous moments steps to a value proportional to the instantaneous amplitude of said signal at said moments, said moments recurring at a rate corresponding to said constant periodicity, means to generate a sawtooth wave having a frequency corresponding to said constant periodicity, a threshold amplifier having a threshold value exceeding the maximum amplitude of said stepped wave, and means to apply said stepped wave and said sawtooth wave additively as an input to said amplifier, whereby output pulses are yielded by said amplifier whose duration is proportional to the instantaneous amplitude of said stepped wave.

5. Apparatus for converting an amplitude-modulated signal into pulses of constant periodicity, the duration of said pulses being dependent on the instantaneous amplitude of said signal, said apparatus comprising means to generate a stepped wave the amplitude of which at isochronous moments steps to a value proportional to the instantaneous amplitude of said signal at said moments, said moments recurring at a rate corresponding to said constant periodicity, means to generate a sawtooth wave having a frequency corresponding to said constant periodicity, a threshold amplifier having a threshold value exceeding the maximum amplitude of said stepped wave, and means to apply said stepped wave and said sawtooth wave additively as an input to said amplifier, whereby output pulses are yielded by said amplifier whose duration is proportional to the instantaneous amplitude of said stepped wave, said moments being coincident in time with the fly-back periods of said sawtooth wave.

6. A system for generating a stepped wave the amplitude of which at isochronous moments steps to a value proportional to the instantaneous amplitude of an applied signal of variable amplitude, said system comprising a storage capacitance, a pair of unidirectional conductive devices each having a control electrode, said devices being oppositely connected in parallel relation, means to apply the signal through said parallel-connected devices across said capacitance, and means to apply concurrently to the control electrodes of said devices pulses of constant periodicity rendering said devices simultaneously conductive.

7. A system for generating a stepped wave the amplitude of which at isochronous moments steps to a value proportional to the instantaneous amplitude of an applied signal of variable amplitude, said system comprising a storage capacitance, a pair of electron discharge devices each having a cathode, a control electrode and an anode, the cathode of each device being connected to the anode of the other device to form a parallel circuit of opposed devices, means to apply the signal through said parallel circuit across said capacitance, and means to impress concurrently on the control electrodes of said devices pulses of constant periodicity to render said devices simultaneously conductive.

8. A system for generating a stepped wave the amplitude of which at isochronous moments steps to a value proportional to the instantaneous amplitude of an applied signal of variable amplitude, said system comprising a charging circuit constituted by a capacitor in parallel with a resistor, a pair of electron discharge devices each provided with a cathode, a grid and an anode, the cathode of each device being connected to the anode of the other device to form a parallel circuit of opposed devices, a transformer having a primary and a secondary, one end of said secondary being connected to one end of said charging circuit and the other end of said secondary being connected through said parallel circuit to the other end of said charging circuit, means to apply the signal to the primary of said transformer, and means to impress concurrently on the grids of said devices pulses of constant periodicity to render said devices simultaneously conductive, whereby a stepped wave is developed across said charging circuit.

9. Apparatus for converting an amplitude modulated signal into pulses of constant periodicity, the duration of said pulses being dependent on the instantaneous amplitude of said signal, said apparatus comprising a system for generating a stepped wave whose amplitude at isochronous moments steps to a value proportional to the instantaneous amplitude of said signal, said system including a storage capacitance, a pair of unidirectional conductive devices each having a control electrode, said devices being oppositely connected in parallel relation, means to apply the signal through said parallel-connected devices across said capacitance and means to apply concurrently to the control electrodes

of said devices impulses at a rate corresponding to said constant periodicity to render said devices simultaneously conductive whereby a stepped wave is developed across said capacitance, a sawtooth wave generator, means to combine the output of said system and said generator to produce a combined wave, and means to derive from said combined wave pulses whose duration is proportional to the instantaneous amplitudes of said stepped wave.

10. In a pulse transmission system wherein the pulses are phase-modulated in accordance with the instantaneous amplitude of an intelligence signal, the combination comprising apparatus for converting said signal into pulses of constant periodicity whose duration is dependent on the instantaneous amplitude of said signal, said apparatus including means to generate a stepped wave the amplitude of which at isochronous moments steps to a value proportional to the instantaneous amplitude of said signal at said moments, said moments recurring at a rate corresponding to said periodicity, means to generate a sawtooth wave having a frequency corresponding to said periodicity, a threshold amplifier having a threshold value exceeding the maximum amplitude of said stepped wave and means to apply said stepped wave and said sawtooth wave additively as an input to said amplifier whereby output impulses are yielded by said amplifier whose duration is proportional to the instantaneous amplitude of said stepped wave, means to differentiate said output impulses to produce first and second pulses of opposite polarity coincident with the leading and trailing edges respectively of said output impulses, means to segregate said first pulses from said second pulses, and means to transmit said first pulses.

11. The method of converting an amplitude-modulated signal into pulses of constant periodicity the duration of which is dependent on the instantaneous amplitude of an amplitude-modulated intelligence signal comprising the steps of converting the signal into a stepped wave the amplitude of which at isochronous moments steps to a value proportional to the instantaneous amplitude of said signal at said moments, said moments recurring at a rate corresponding to said constant periodicity, generating a sawtooth wave whose frequency corresponds to said constant periodicity, additively combining said stepped wave and said sawtooth wave, and deriving from the combined wave pulses whose duration depends on the instantaneous amplitude of said stepped wave.

12. The method of converting an amplitude-modulated signal into pulses of constant periodicity, one corresponding edge of each pulse having a position which is dependent on the instantaneous amplitude of an amplitude-modulated intelligence signal, comprising the steps of converting the signal into a stepped wave the amplitude of which at isochronous moments steps to a value proportional to the instantaneous amplitude of said signal at said moments, said moments recurring at a rate corresponding to said constant periodicity, generating a sawtooth wave whose frequency corresponds to said constant periodicity, additively combining said stepped wave and said sawtooth wave, and deriving from the combined wave pulses having one corresponding edge whose position depends on the instantaneous amplitude of said stepped wave.

13. Apparatus for converting an amplitude-modulated signal into pulses of constant periodicity, one corresponding edge of each pulse having a position which is dependent on the instantaneous amplitude of said signal, said apparatus comprising means to generate a stepped wave the amplitude of which at isochronous moments steps to a value proportional to the instantaneous amplitude of said signal at said moments, said moments recurring at a rate corresponding to said constant periodicity, and means to convert each step of said wave into a pulse one of whose edges has a position which is proportional to the amplitude of said step.

KLAAS POSTHUMUS.

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