Nov. 23, 1954 M. M. LEVY 2,695,359

ELECTRIC PULSE-SIGNALING SYSTEM RECEIVER

Original Filed Jan. 6, 1949

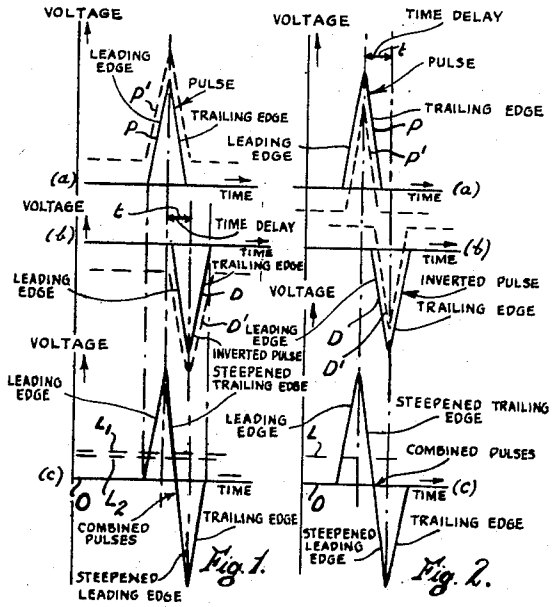


Fig. 1.

Fig. 2.

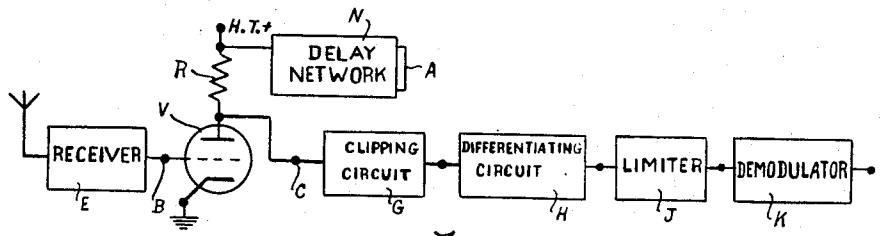


Fig. 3.

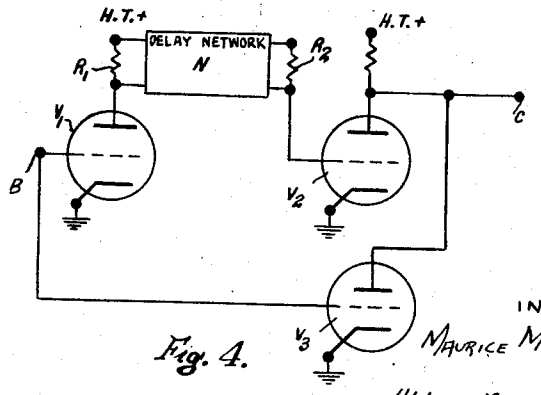


Fig. 4.

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United States Patent Office 2,695,359 Patented Nov. 23, 1954

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ELECTRIC PULSE-SIGNALING SYSTEM RECEIVER

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Continuation of application Serial No. 69,441, January 6, 1949. This application December 14, 1953, Serial No. 397,844

4 Claims. (Cl. 250—20)

The present invention relates to electric pulse signalling systems and is a continuation of application Serial No. 69,441, filed on January 6, 1949, now abandoned. It is applicable with many kinds of pulse modulation, such as time, width and amplitude modulation, but for simplicity it will be described with particular reference to time modulation.

The invention has for its object to enable the signal to noise ratio to be improved and, in multi-channel systems, also to enable cross-talk to be reduced, at a terminal or repeater, radio or cable receiving station.

According to the present invention these objects are attained by the provision of a method of receiving a train of electric pulses, each said pulse having inclined leading and trailing edges and at least one of said edges being time-modulated in accordance with a signal, said method comprising generating from the received pulse train a second train of substantially the same waveform as the received train but reversed in sign, time-displacing one of said trains relatively to the other by an amount to cause at least a part of the leading edge of each pulse of one train to occur at the same time as at least a part of the trailing edge of a pulse of the other train, combining said trains to produce a resultant having portions of inclination greater than that of either of said edges, and extracting the modulation from the said portions.

The invention will be described by way of example with reference to the accompanying drawings in which

Figures 1 and 2 are diagrams illustrating the invention and Figures 3 and 4 are circuit diagrams showing essential features of two embodiments of the invention.

In describing the invention it will be assumed that the pulses concerned are voltage pulses having a triangular waveform as indicated at P in full lines in Figure 1(*a*) and Figure 2(*a*) which show the pulses represented as a graph of voltage against time. In practice pulses always depart more or less from a true rectangular shape and a sufficiently accurate picture of practical conditions can be obtained by the assumption of triangular pulses. Noise voltages having periods long compared with the duration of a pulse will cause the pulse as a whole, and the voltage base line from which it extends, to rise and fall as indicated by the broken line P′ in Figure 1(*a*) and Figure 2(*a*).

Now according to this invention there is generated from a received train of pulses of the character shown in Figures 1(*a*) and 2(*a*) a second train of pulses of opposite polarity as shown in Figures 1(*b*) and 2(*b*) at D and D′ (corresponding to P and P′ respectively in Figures 1(*a*) and 2(*a*)). This may be done in any convenient way, for instance by the use of a thermionic valve. Moreover a suitable relative time displacement of the two trains is produced, either train being retarded relatively to the other, by means of a suitable delay network. The time delay is less than one pulse width and greater than half a pulse width. In Figures 1 and 2 it is indicated by the arrows marked *t* and is a little more than half a pulse width.

If the voltage of the two trains of pulses, one of positive and the other of negative pulses as shown respectively in Figures 1(*a*) and (*b*) or Figures 2(*a*) and (*b*), are now added together, an increase in voltage due to noise in a positive pulse (and its base line) will be accompanied by a decrease in voltage of the corresponding negative pulse (and its base line); that is to say a given noise voltage causes one pulse to become more positive and the other more negative. If the amplitudes of the

pulses of the two trains are the same, the noise voltages will cancel one another and the pulses of the resultant trains will be as shown in Figures 1(*c*) and 2(*c*). As shown, the resultant train will consist of pairs of pulses, one positive and the other negative, the waveform of these pulses being unaffected by the noise.

It will be evident from a consideration of Figures 1 and 2 that perfect cancellation of an undesired voltage can only be obtained when such voltage is constant. On the other hand a great reduction in such undesired voltage can be obtained so long as its period is long compared with the duration of a pulse for, in such cases, the extent to which the pulses are raised and lowered respectively in Figures 1(*a*) and 2(*a*) will be nearly equal to the extent to which they are lowered and raised, respectively, at the same instants in Figures 1(*b*) and 2(*b*).

Figure 3 shows the essential part of a simple circuit whereby the pulse trains illustrated in Figures 1(*c*) and 2(*c*) can be obtained from the pulse trains illustrated in Figures 1(*a*) and 2(*a*) respectively. A valve V has connected across its anode load R a delay network N short-circuited at its end A. The time-delay introduced by the network N from R to A and back to R is made equal to *t*, the delay time between the pulses of Figures 1(*a*) and (*b*) or Figures 2(*a*) and (*b*). The pulse train illustrated in Figure 1(*a*) for example is applied from a receiver E, shown as a radio receiver, to the input terminal B and the pulse train illustrated in Figure 1(*c*) is obtained at terminal C. The load resistor R is chosen such that negligible reflection takes place at this resistor. Phase reversal takes place in this case at the short-circuited end A. Suitable delay networks and circuits including these networks are described in the Journal of the Institute of Electrical Engineers of Great Britain (J. I. E. E.), vol. 93, part III*a*, No. 1, at pages 312–314.

In Figure 4 a circuit is shown in which phase reversal is effected by the use of two stages of amplification for the delayed train and only one stage for the undelayed train. Thus there are provided two valves V_1 and V_2 coupled by a delay network N having a delay time between its terminating resistors R_1 and R_2 equal to *t*. A third valve V_3 is inserted directly between the input and output terminals B and C. In this case no reflection is required at either end of the network N and both terminations are, therefore, arranged to be matched.

In order to obtain the modulation from the resultant pulses at (*c*) in Figures 1 and 2, any known or suitable means may be used. Either the positive or the negative pulses, or any suitable part thereof, may be used and if desired both the positive and the negative pulses may be demodulated separately and the resulting modulation voltages may be added together.

If the pulses are received in the form of bursts of a carrier frequency oscillation, they are preferably rectified before application of the present invention. Preferably the carrier frequency is also eliminated since otherwise the phase relationship of the carrier oscillations in the two trains has to be carefully adjusted.

It is usual, before demodulating pulses, to "clip" them, that is to say to extract therefrom, only voltages between two closely-spaced limits. When clipping is carried out before application of the invention, care must be taken that the clipping does not remove the noise from that part of either of the pulses which contributes to the part of the resultant thereof used in demodulation, as otherwise the cancellation of noise can obviously not occur. When clipping is carried out upon the resultant obtained from application of the invention this point does not arise.

As shown in Figure 1(*c*), the clipping may for example be effective between the voltages represented by the two broken lines L_1 and L_2, only the parts of the waveform between these limits being passed to a demodulating circuit. The clipping circuit may be of known type (for example as described in J. I. E. E., vol. 93, part III*a*, No. 1, at page 296, section 6.1 and Figure 13) and is indicated at G in Figure 3. In order to arrange that even with noise of the most unfavourable frequencies there is no increase in the noise level, the delay chosen is, as exemplified in Figures 1 and 2, between one half of the pulse width and the whole pulse width when the pulses have the triangular shape shown. In any case the delay is made such that at

least part of the leading edge of one train (the delayed train at (*b*) in Figures 1 and 2) occurs at the same time as at least a part of the trailing edge of the other train (that at (*a*) in Figures 1 and 2). The result of this is that the resultant of the two parts referred to has a steepness which is the sum of the steepness of the parts, and, provided that use is made of the steep parts in demodulating, the increase in noise which would otherwise occur at certain high frequencies is counteracted by the increase in steepness.

If clipping be effected between the voltage limits represented by the lines L_1 and L_2 in Figure 1(*c*) the edge of the pulses obtained which is used for demodulation should be the trailing edge. One way of doing this, as is known, and illustrated diagrammatically in Figure 3, is to differentiate the limited pulses from the clipping circuit G by means of a differentiating circuit H (as described in J. I. E. E., vol. 93, part III*a*, No. 1, at pages 293–6 with reference to Figure 7(*b*)) and to select by a further limiter J (as described in J. I. E. E., vol. 93, part III*a*, No. 1, at pages 296–7 with reference to Figure 14) the pulses corresponding to the trailing edges. These pulses may be demodulated directly in a demodulator K by conversion in known manner to width-modulation and by means of a low-pass filter. An example of a circuit for carrying this out is described in J. I. E. E., vol. 94, part III*a*, No. 13 in section 3.2.3 at page 577. Alternatively, the pulses shown in Figure 1(*c*) may first be applied to shock-excite a tuned circuit for example as described in the specification of co-pending U. S. Patent Application No. 55,731 (since matured as U. S. Patent No. 2,654,028). If the tuned circuit is strongly damped, the first positive peak will be produced substantially by the trailing edge only. In the circuits shown in Figures 3 and 4, a suitable source of high tension voltage (not shown in the drawing) for operating the valves is connected in known manner across the terminals marked "HT+" and earth, the positive side of this source being connected to the terminals HT+ and the negative side to earth.

In a multi-channel pulse system, using time modulation, the different channels are interlaced with one another in time and cross-talk may occur between adjacent channels in either of two ways. Firstly the circuits through which the signal passes may be such as to introduce an exponential "tail," that is to say the pulse energy dies away exponentially, and there may be appreciable energy still existing in the system from one channel at the time corresponding to the centre of the next channel. It should be noted that it is only energy from an adjacent channel persisting to the neighbourhood of the centre part of a channel that is in practice seriously objectionable since it is usually only when the amplitude of modulation is relatively low that noise is objectionable.

The invention can be used to reduce substantially such cross-talk. For this purpose, and if desired also when the objective is only noise reduction, means may be provided for adjusting the relative amplitude and/or delay time of the positive and negative trains in order to secure minimum cross-talk or noise.

In forms of the invention so far described, it has been explained how a leading or trailing edge of increased steepness can be produced as the resultant of the leading edge of one pulse and the trailing edge of its inverse. If desired two such steepened edges can be produced by combining with a received pulse inverted pulses one suitably advanced and the other suitably delayed relatively to the received pulse. One of these steepened edges is the resultant of the leading edge of the received pulse and the trailing edge of the earlier of the inverted pulses and the other steepened edge is the resultant of the trailing edge of the received pulse and the leading edge of the later of the inverted pulses.

Use may be made of both these steepened edges to produce modulation frequency voltages in which the noise is reduced.

I claim:

1. Apparatus for electric pulse-signalling comprising means for receiving a train of modulated pulses, each of said pulses having inclined leading and trailing edges means for generating from the received pulse train a second train which is of substantially the same waveform as the received train but reversed in sign, means for time-displacing one of said trains by more than half the width of one of said pulses, and less than the width of such pulse, relatively to the other of said trains, means for combining said trains additively to produce a resultant including a portion whose inclination is the sum of the inclinations of a part of a leading edge of each pulse of one train and a part of a trailing edge of a pulse of the other train, means for differentiating at least a part of said portion and demodulating means responsive to at least a part of the output from said differentiating means.

2. Apparatus for electric pulse-signalling comprising means for receiving a train of modulated pulses, each of said pulses having inclined leading and trailing edges, means for generating from the received pulse train a second train which is of substantially the same waveform as the received train but reversed in sign, means for time-displacing one of said trains by more than half the width of one of said pulses, and less than the width of such pulse, relatively to the other of said trains, means for combining said trains additively to produce a resultant including a portion whose inclination is the sum of the inclinations of a part of a leading edge of each pulse of one train and a part of a trailing edge of a pulse of the other train, a clipping circuit for extracting from the said portion only voltages between two closely-spaced limits, a differentiating circuit for differentiating the output from said clipping circuit, amplitude limiting means for selecting only part of the output from said differentiating circuit and demodulating means for extracting the modulation from the output of said amplitude limiting means.

3. A method of receiving a train of electric pulses, each said pulse having inclined leading and trailing edges and at least one of said edges being time-modulated in accordance with a signal, said method comprising generating from the received pulse train a second train of substantially the same waveform as the received train but reversed in sign, time-displacing one of said trains relatively to the other by an amount to cause at least a part of the leading edge of each pulse of one train to occur at the same time as at least a part of the trailing edge of a pulse of the other train, combining said trains to produce a resultant having portions of inclination greater than that of either of said edges, and extracting the modulation from the said portions.

4. A method of receiving a train of electric pulses, each said pulse having inclined leading and trailing edges and at least one of said edges being time-modulated in accordance with a signal, said method comprising generating from the received pulse train a second train of substantially the same waveform as the received train but reversed in sign, time-displacing one of said trains relatively to the other by a time which is less than the duration of a pulse by an amount not exceeding the duration of one of said edges, combining said trains to produce a resultant having portions of inclination greater than that of either of said edges, and extracting the modulation from the said portions.

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