Feb. 25, 1947. D. D. GRIEG 2,416,305

RADIO RECEIVER

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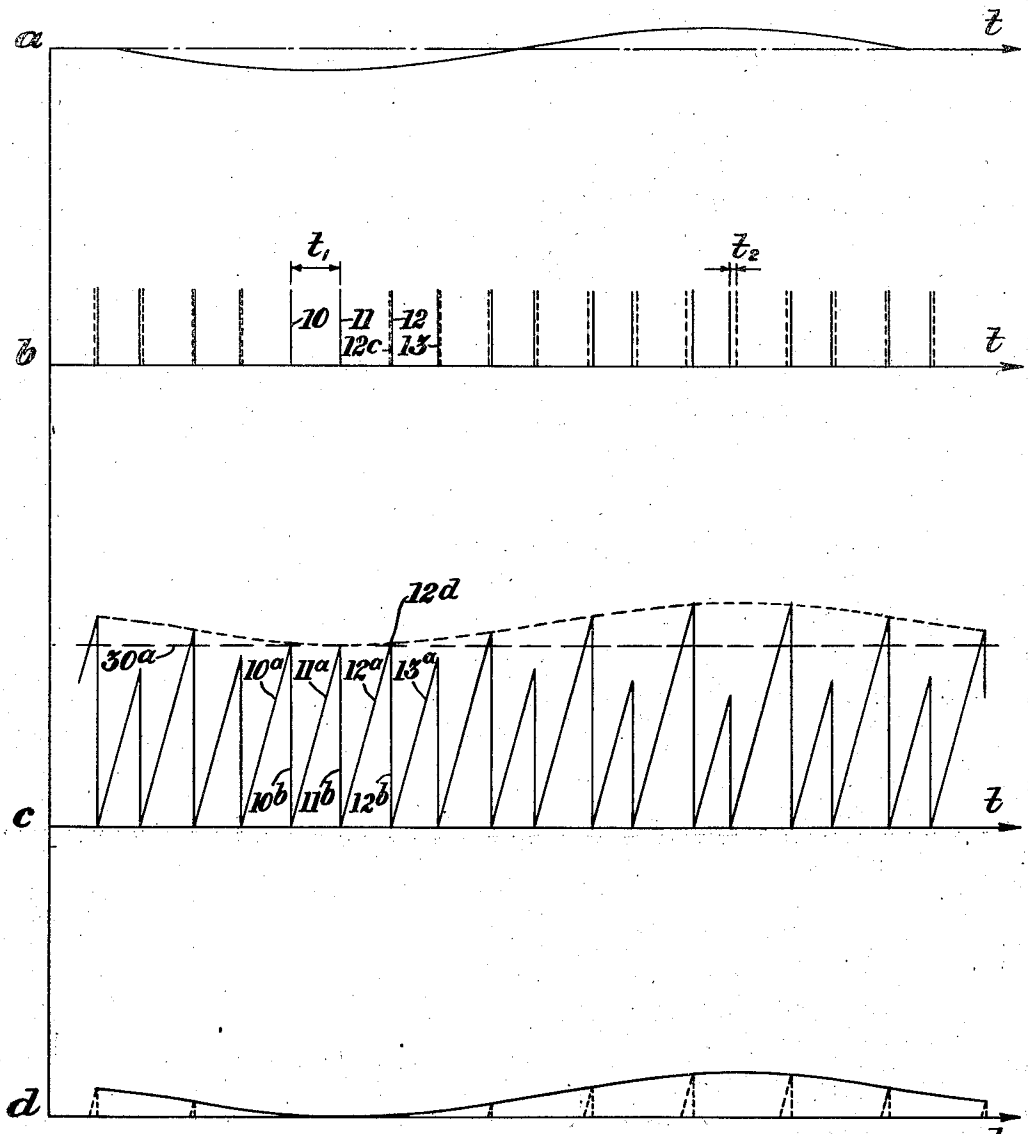
Fig:1.



INVENTOR
DONALD D. GRIEG
BY Percy P. Lantzy
ATTORNEY

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Fig:2.

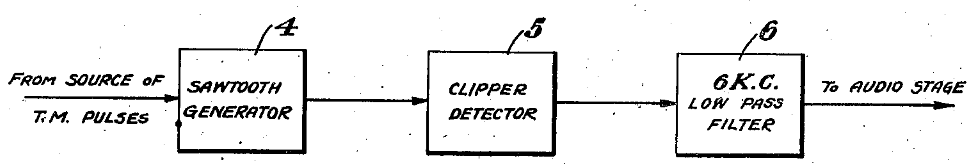
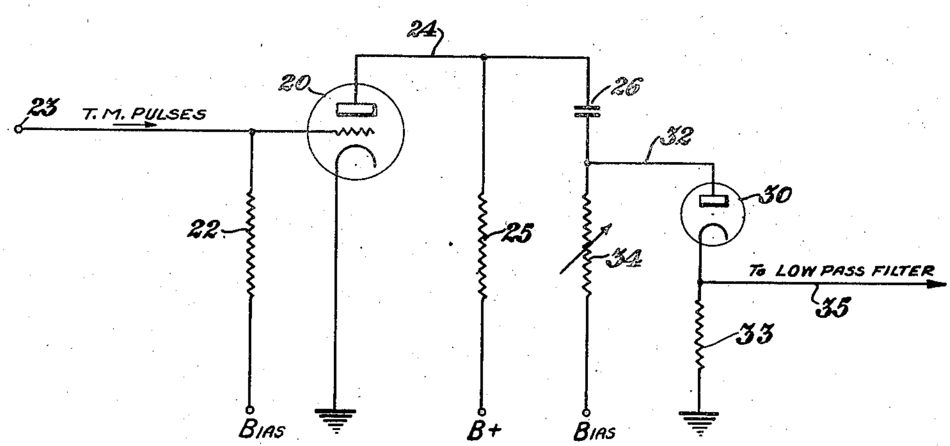


Fig:3.



INVENTOR
DONALD D. GRIEG
BY Percy P. Lantzy
ATTORNEY

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UNITED STATES PATENT OFFICE

2,416,305

RADIO RECEIVER

Donald D. Grieg, Forest Hills, N. Y., assignor to Federal Telephone and Radio Corporation, a corporation of Delaware

Application September 18, 1942, Serial No. 458,854

12 Claims. (Cl. 250—20)

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This invention relates to radio reception and demodulation of time modulated pulse energy and more particularly to a method and means for translating time modulated pulse energy into amplitude modulated pulse energy.

Pulse modulation systems to which this invention relates generally are disclosed in the U. S. Patents to A. Reeves Nos. 2,266,401 and 2,256,336; U. S. Patent to E. Deloraine and A. Reeves 2,262,-838; and in copending application of E. Labin entitled "Pulse modulation system," Serial No. 386,-282, filed April 1, 1941; and copending application of E. Deloraine and E. Labin entitled "Pulse transmission system," Serial No. 425,108, filed December 31, 1941.

In accordance with pulse modulation recurring pulses or pairs of pulses, as the case may be, can be used where variations of the spacing between pulses correspond to signal increments. Where recurring pairs of pulses are used, time modulation may comprise displacement of the pulses toward and away from each other in push-pull manner or one of each pair may be fixed and the other displaced relative thereto in accordance with a signal increment. While the pairs of pulses may be amplitude modulated as well as time modulated for simultaneous transmission of two different signals, this invention is concerned only with demodulation of the time modulation part thereof.

One of the objects of this invention therefore, is to provide a method and means for demodulating time modulated pulse energy received from pulse modulating systems such as those in the aforesaid U. S. Patents and copending applications.

Another object of the invention is to provide a simplified method and means for translating time modulated pulse energy into amplitude modulated pulse energy.

Still another object of the invention is to provide a method and means for translating time modulated pulse energy into envelopes of amplitude modulation which may be filtered and applied directly to a speaker.

Briefly, the method of this invention comprises generating a wave having recurring peaks such, for example, as a sawtooth wave, controlling the amplitudes of the peaks thereof in accordance with the length of the time intervals between the pulses of time modulated pulse energy and clipping off the portion of the wave below a level or threshold such as is determined by the peak amplitude of a wave formed by a time interval between pulses corresponding to the maximum

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negative modulation value. Such a level will provide for 100% demodulation. This provides carrier pulses forming an amplitude envelope in accordance with the time modulated pulse energy. By passing the envelope energy through a low pass filter to remove carrier pulse harmonics, an energy output in accordance with the modulation is produced which may be applied directly to a speaker or other intelligence translating device.

Should the modulated pulse energy include amplitude modulation as well as time modulation, the amplitude modulation may be detected in known manner and the pulse energy passed to a sawtooth generator and clipping device for translation of the time modulated signals to amplitude modulated pulses for intelligent reception in accordance with the method described above.

For a further understanding of the method of this invention reference may be had to the accompanying detailed description of a form of apparatus by which this method may be practiced, the detailed description to be read in connection with the accompanying drawings, in which:

Fig. 1 is a graphical illustration in accordance with this invention;

Fig. 2 is a block diagram of a form of apparatus which may be used in practicing the method; and

Fig. 3 is a schematic illustration of an electrical circuit showing details of parts of the apparatus of Fig. 2.

Assuming that a train of pulses is time modulated in accordance with a sine wave *a* (Fig. 1) the time modulated relation of the pulses for a cycle of the modulating wave is shown by the pulse positions *b*. The spacing of the pulses is greatly exaggerated for purposes of illustration, it being understood that the spacing t_1 for unmodulated pulses having a transmission frequency of 6 kilocycles, for example, is about 80 microseconds, while the maximum degree of pulse modulation or displacement as indicated by the interval t_2 is equal to from one to 2 microseconds thereabouts. It will thus be clear that where the pulses are observed on the usual oscillograph, the degree of modulation as compared with the spacing between adjacent pulses is so slight as not to be readily perceptible. It is this feature of pulse time modulation that is so useful for the sending of secret messages.

In the block diagram shown in Fig. 2, time modulated pulses are first applied to a wave generator 4 adapted to produce a wave having recurring inclined portions similar to a sawtooth shape. For purposes of illustration a pure sawtooth wave is used as indicated by the wave *c* (Fig. 1). Alternate teeth of the wave thus generated are varied in direct amplitude in proportion to the time variation of the intervals between adjacent pulses. This sawtooth wave is then passed through a clipper detector **5** which is biased to clip off the sawtooth wave below a level **30***a* such as is determined by the amplitude of the sawtooth waves formed in accordance with the spacing between pulses corresponding to the maximum negative modulation value. This clipped portion of the sawtooth wave provides a series of pulses which form envelope energy such as illustrated by the curve *d*. This envelope energy is then passed through a low pass filter **6**, for example, of 6 kilocycles for the elimination of carrier pulse harmonics. The output modulated wave from the filter may then be passed to an audio amplifier stage or directly to earphones or a speaker.

Referring more particularly to Figs. **1** and **3**, the sawtooth generator is shown to comprise a form of relaxation oscillator having a high vacuum triode tube **20**. The tube **20** is biased through a resistance **22** to a desired cut-off level. The time modulated pulses are applied to the grid terminal **23**. The plate circuit **24** of the tube **20** is supplied with a positive potential through a resistance **25** which functions when the plate current of the tube **20** is cut off to charge a condenser **26**. Connected to the condenser is a peak rectifier tube **30** which serves as the clipper detector. The tube **30** prevents passage therethrough of sawtooth wave energy below a value or threshold depending upon the value of the negative bias connected through a variable resistor **34** to the plate circuit **32** thereof.

When the tube **20** reaches cut-off and becomes non-conductive, the potential drop through the resistor **25** becomes low and a charge builds up in the condenser **26**. The charging rate of the condenser **26** gives a normal sloping characteristic of the sawtooth oscillation. When this charging potential exceeds the cut-off level of the tube **30**, current will begin to flow through the tube **30** and resistor **33** and produce a voltage at the output **35**. The cut-off level of tube **30**, however, is chosen to occur in accordance with the spacing between pulses corresponding to the maximum negative modulation value received at the input terminal **23**. Thus should a pair of such pulses **10** and **11** be received at the terminal **23**, the timing of the sawtooth oscillation is such that the impulse **10** will operate the tube **20** causing the condenser **26** to discharge through the tube **20**. This condition is illustrated in Fig. 1 by the built-up slope **10***a* and the vertical discharge line **10***b*. Immediately after reception of pulse **10** and the resulting discharge of condenser **26** the voltage from B+ begins to recharge the condenser. This charging rate is represented by the slope **11***a* which is parallel to the slope **10***a* and terminates the instant pulse **11** is received as indicated by the discharge line **11***b*. This amplitude of sawtooth **11***a* is taken as the value at which the rectifier is biased for passage of energy, and is represented by the line **30***a*. At the zero end of the line **11***b*, the condenser **26** begins to recharge forming a slope **12***a*. The slope **12***a* continues until the next succeeding pulse **12** is received whereupon the amplitude of the sawtooth slope **12***a* is terminated by the discharge line **12***b*. Since the pulse **12** is slightly time modulated, that is, displaced slightly from the position **12***c*, the slope **12***a* has had time to build up beyond the cut-off level **30***a*. Thus, a small amount of energy represented by the peak **12***d* extending beyond the line **30***a* has passed through the tube **30**. The next succeeding pulse **13**, however, is time modulated in an opposite direction from the direction of modulation of the pulse **12** so that the next sawtooth slope **13***a* does not reach the amplitude level of the line **30***a* by the time the pulse **13** is received. Thus the sawtooth slope **13***a* is terminated below the line **30***a*.

It will be seen that time modulation in accordance with the sine wave *a*, provides alternately high and low pulses in accordance with the degree of modulation. The peaks of the high amplitude sawteeth comprise carrier pulses and together form an envelope *d* in accordance with the time modulation of the pulses.

While I have shown for purposes of illustration a modulation in accordance with a sine wave, it will be clear that modulation by voice or other forms of signals may be transmitted by time modulation and demodulated in accordance with this invention to provide a translation to amplitude pulse modulation. This amplitude modulation is provided by the sawtooth peaks which provide a substantial amount of energy for the wave. The envelope wave, however, may be passed through an audio-amplifier or after having been filtered to remove the carrier pulses may be passed directly to a speaker.

It will be recognized that demodulation in accordance to this invention is applicable to various forms of pulse modulation wherever the modulation is effected by variation of the spacing or time intervals between pulses. Thus, even for pairs of pulses where one pulse recurs at fixed intervals and the other pulse occurs at varying intervals in accordance with modulation, the variation of spacing between adjacent pulses of a wave train of each pulse pairs can be used to control the build-up of wave peaks as hereinbefore described. Likewise, where the pulse pairs are spaced apart a larger interval than the spacing of the pulses of each pair, the time modulation of the pulses of each pair provide variation in spacing between the pulses of a wave train thereof whereby translation to amplitude modulation may be made in accordance with this invention.

While I have shown and described but one form of apparatus by which the method of this invention may be practiced, I recognize that other apparatus as well as variations of the form of apparatus herein shown and described may be made without departing from the invention. It will be understood, therefore, that the form of apparatus herein shown and described is to be regarded as illustrative of the invention only and not as restricting the appended claims.

What is claimed is:

1. A method for translating a train of time modulated pulse energy into an amplitude modulated pulse wave, comprising initiating generation of a period of said wave having voltage increasing according to a given pattern with time in accordance with the occurrence of a pulse of said time modulated pulse energy, terminating said generation and initiating generation of a new period of said wave by the occurrence of the next succeeding pulse of said time modulated pulse energy, and threshold clipping said wave at an amplitude corresponding to the amplitude of a period of said wave produced by two succeeding pulses of maximum negative modulation.

2. A method for translating a train of push-pull time modulated pulse energy into an ampli-

tude modulated pulse wave comprising initiating generation of a period of said wave in accordance with the occurrence of a pulse of said time modulated pulse energy, said period being in the form of a sawtooth, terminating said generation and initiating generation of a new sawtooth period by the occurrence of the next succeeding pulse of said time modulated pulse energy, and threshold clipping said wave at an amplitude corresponding to the amplitude of a sawtooth produced by two succeeding pulses of maximum negative modulation.

3. A method for translating a train of time modulated pulse energy into an amplitude modulated pulse wave comprising initiating generation of a period of said wave having voltage increasing according to a given pattern with time in accordance with the occurrence of a pulse of said time modulated pulse energy, terminating said generation and initiating generation of a new period of said wave by the occurrence of the next succeeding pulse of said time modulated pulse energy, threshold clipping said wave at an amplitude corresponding to the amplitude of a period of said wave produced by two succeeding pulses of maximum negative modulation, thereby providing an amplitude envelope in accordance with time modulation of said pulse energy, and filtering the envelope energy to remove pulse harmonics.

4. A method for translating a train of time modulated pulse energy into an amplitude modulated wave, wherein succeeding pairs of pulses define signal increments by the relative time displacement of said pulses in accordance with a modulating signal wave, said time modulated pulses being characterized by the alternate and intermediate pulses being displaced in push-pull manner toward or away from their succeeding pulses according to the instantaneous amplitude of the signal wave with which said pulses are modulated; said method comprising initiating generation of a sawtooth voltage by the occurrence of one of the pulses of said time modulated pulses, terminating the sawtooth generation and initiating generation of a new sawtooth by the occurrence of the next succeeding pulse of said time modulated pulses, and threshold clipping said sawtooth voltage at an amplitude level determined by the amplitude of a sawtooth produced by two succeeding pulses of maximum negative modulation, thereby obtaining a succession of sawtooth pulses defining envelopes corresponding to the modulating signal wave.

5. A method for translating a train of time modulated pulses into an amplitude modulated wave, wherein pairs of pulses are used to define a signal increment by relative time displacement of said pulses in accordance with a modulating signal wave, said time modulated pulses being characterized by the alternate and intermediate pulses being displaced toward or away from their succeeding pulses according to the instantaneous amplitude of the signal wave with which said pulses are modulated; comprising initiating generation of a sawtooth voltage by the occurrence of one of the pulses of said time modulated pulses, terminating the sawtooth generation and initiating generation of a new sawtooth by the occurrence of the next succeeding pulse of said time modulated pulses, threshold clipping said sawtooth voltage at an amplitude level determined by the amplitude of a sawtooth produced by two succeeding pulses of maximum negative modulation, thereby defining amplitude envelopes in accordance with time modulation of said pulse energy, and filtering the envelope energy to remove pulse harmonics.

6. A demodulator for translating a train of time modulated pulse energy into amplitude modulated pulse energy wherein the said time modulated pulses are characterized by at least one set of alternate pulses being displaced toward or away from the intermediate pulses according to the instantaneous amplitude of the signal wave with which said pulses are modulated, comprising generator means to generate a voltage wave increasing according to a given pattern with time, means controlling operation of said generator means in accordance with the pulses of said time modulated pulse energy, whereby generation of a period of said voltage wave is terminated and a new period is initiated by each pulse, the amplitude of the periods being thereby controlled in accordance with the time intervals occurring between succeeding pulses of the time modulated pulse energy, and means to clip off the portion of said voltage wave below a level determined by the amplitude of two succeeding pulses whose modulation is of maximum negative value thereby providing amplitude envelope energy in accordance with the time modulation of said train of pulse energy.

7. The demodulator defined in claim 6 wherein the voltage wave generating means comprises a relaxation oscillator.

8. The demodulator defined in claim 6 wherein the wave clipping means comprises a peak rectifier.

9. The demodulator defined in claim 6 wherein the voltage wave generating means comprises a relaxation oscillator and the clipping means comprises a peak rectifier.

10. A demodulator for translating time modulated pulse energy into amplitude modulated energy wherein pairs of pulses define signal increments by relative time displacement of the pulses in accordance with a modulating signal wave, said time modulated pulses being characterized by the alternate and intermediate pulses being displaced in push-pull manner toward or away from their succeeding pulses according to the instantaneous amplitude of the signal wave, comprising means to generate an energy wave of generally sawtooth form, means to control the amplitude of the sawteeth in accordance with the time intervals occurring between pulses of the time modulated pulse energy, the varying of the time interval between pulses resulting in alternately high and low sawteeth, means to clip off the portion of said wave below an amplitude determined by a sawtooth formed in accordance with the spacing between unmodulated pulses, thereby providing envelope energy of sawteeth energy exceeding the clipping amplitude, and means to filter the envelope energy to remove pulse harmonics therefrom.

11. A modulator for translating time modulated pulse energy into amplitude modulated pulse energy, comprising a relaxation oscillator to generate a sawtooth wave, means to control the operation of the relaxation oscillator in accordance with the lapse of time between adjacent pulses of the time modulated pulse energy so that the amplitudes of the sawteeth of said wave correspond with the time intervals between adjacent pulses, and a peak rectifier connected to the output of said oscillator arranged to only pass sawtooth energy above an amplitude level determined by the amplitude of two pulses of maxi-

mum negative modulation whereby amplitude envelope energy is produced in accordance with the modulation of said time modulated pulse energy.

12. A method for translating a train of time modulated pulses into an amplitude modulated wave, wherein the said time modulated pulses are characterized by at least one set of alternate pulses being displaced toward or away from the intermediate pulses according to the instantaneous amplitude of the signal wave with which said pulses are modulated, comprising initiating generation of a sawtooth voltage by the occurrence of one of the pulses of said time modulated pulses, terminating the sawtooth generation and initiating generation of a new sawtooth by the occurrence of the next succeeding pulse of said time modulated pulses, and threshold clipping said sawtooth voltage at an amplitude level determined by the amplitude of a sawtooth voltage produced by two succeeding pulses of maximum negative modulation.

DONALD D. GRIEG.

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