

May 25, 1948.

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2,441,957

DEMODULATOR FOR FREQUENCY MODULATED WAVES

Filed Nov. 13, 1942

2 Sheets-Sheet 1

Fig. 1.

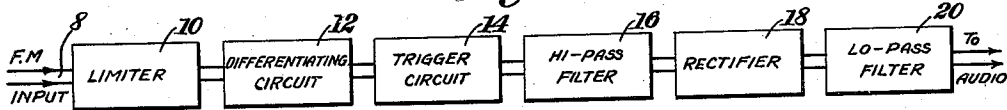
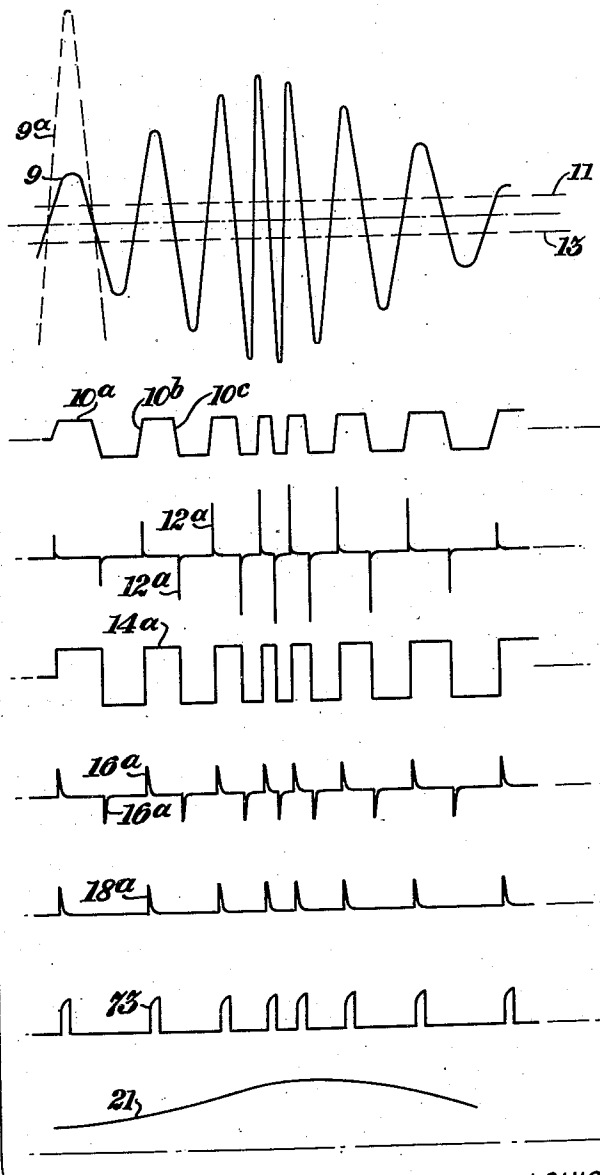


Fig. 2.



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Fig. 3.

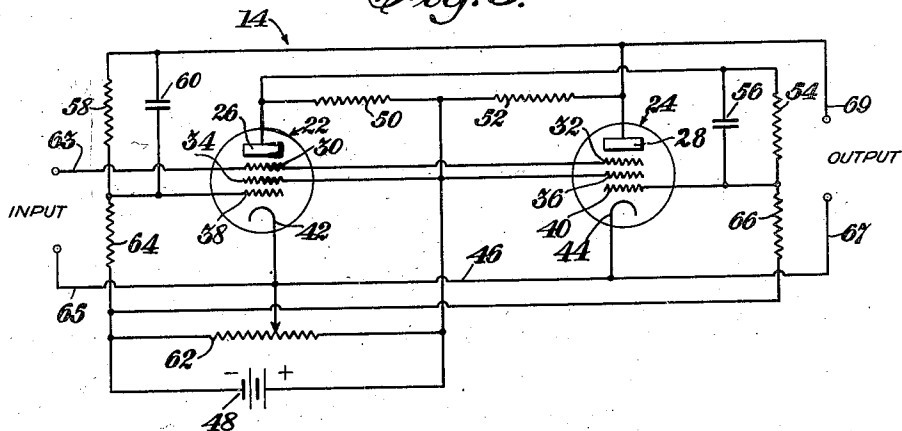


Fig. 4.

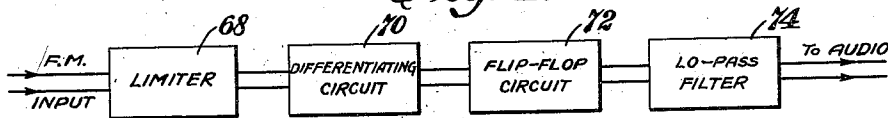
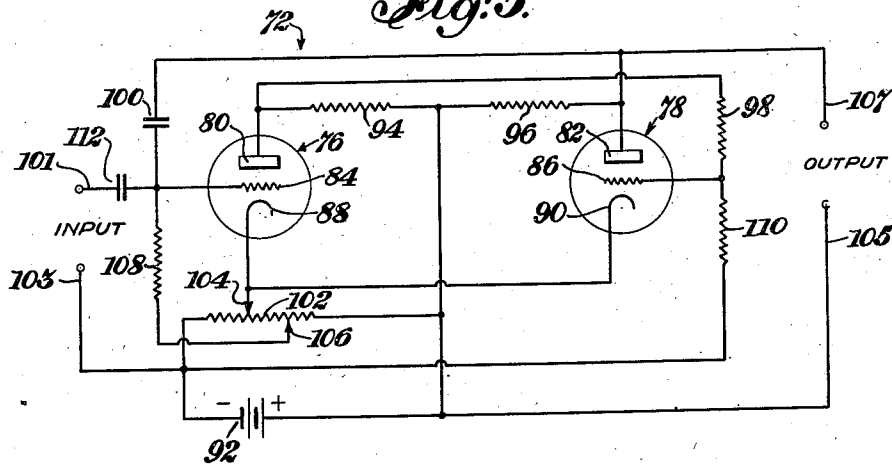


Fig. 5.



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DEMODULATOR FOR FREQUENCY
MODULATED WAVES

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6 Claims. (Cl. 250-27)

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This invention relates to radio and more particularly to demodulation systems.

One of the objects of this invention is to provide a method and means to effect demodulation of energy from a frequency modulated wave source.

A frequency modulated wave may be caused purposely or otherwise to have variations in amplitude as well as frequency. These variations in amplitude, however, render it difficult to obtain accurate demodulation of the frequency modulation signals. Accordingly, it is another object of my invention to provide for the demodulation of frequency modulated waves whereby effects due to amplitude variations present in a frequency modulated wave are greatly minimized if not entirely eliminated during the demodulation process.

The above objects and others ancillary thereto, will become more apparent from the following detailed description to be read in connection with the accompanying drawings, in which:

Fig. 1 is a block diagram of a demodulation system in accordance with my invention;

Fig. 2 is a graphical illustration of the method steps of the invention;

Fig. 3 is a schematic diagram of a component part of the system shown in Fig. 1;

Fig. 4 is a block diagram of another form of demodulation system; and

Fig. 5 is a schematic diagram of a component part of Fig. 4.

Referring to Figs. 1 and 2, the system shown therein is particularly adapted to demodulate a frequency modulated wave having present therein amplitude modulation or at least variations of amplitude whereby the distortion effects of such amplitude variations are greatly minimized if not entirely eliminated from the final reception output of the frequency modulation signals. The system comprises a known form of limiter 10 to which energy from a frequency modulated input source 8 is applied wherein the peaks of the incoming frequency modulated wave 9 are clipped off at levels 11 and 13. This produces a wave 10a which is approximately rectangular in shape. This wave is then differentiated by passing it through a differentiating circuit 12 so as to produce alternate positive and negative pulses 12a in accordance with the arrival of each positive and negative half cycle of the input wave.

The side slopes 10b and 10c of the wave 10a, however, vary in steepness in accordance with amplitude variations and this variation in steepness is reflected in the amplitude of the pulses 12a. This increased steepness for larger amplitudes is

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indicated by the wave 9a. The wave 9 is shown to vary in amplitude as well as in frequency to further illustrate the effects of amplitude variation in the pulses 12a. Frequency modulation also produces some variation in the amplitude of the pulses 12a, but since the modulations in frequency are usually of very small percentage, the effect thereof in amplitude of the pulses 12a is negligible. The amplitude variations of pulses 12a, regardless of course, are satisfactorily removed by my method of demodulation.

The pulses 12a are next subjected to a translating process including the operation of the circuits 14, 16 and 18. The pulses 12a are first passed through a trigger circuit 14 so as to produce a second rectangular wave 14a having substantially vertical sides and equal amplitude. As hereinafter described in detail, the circuit 14 is arranged to be triggered successively from one state of operation to another by one of the pulses 12a and then back to the first-mentioned state of operation by the next succeeding pulse, etc. By differentiation in a high-pass filter 16, a series of positive and negative pulses 16a of substantially constant amplitude are produced. The amplitude variations appearing in the wave 9 and in the pulses 12a are thus eliminated. By passing the pulses 16a through a rectifier 18, a wave train of positive constant amplitude pulses 18a is produced in which the pulses occur at the beginning of each positive half cycle of the input wave 9. These positive pulses are passed through a low-pass filter 20 and integrated thereby producing an audio wave 21 which varies with the frequency of the incoming frequency modulated wave 9. Thus, the frequency modulation signal is detected without any distortion due to amplitude variations present in the input wave.

In Fig. 3, I have shown a schematic diagram of a trigger-type of multi-vibrator circuit 14 suitable for use in my invention. The circuit comprises vacuum tubes 22, 24 having respectively, plates 26 and 28; suppressor grids 30, 32; screen grids 34, 36; control grids 38, 40 and cathodes 42, 44; said cathodes being joined by a common connecting means 46. Plate 26 of tube 22 receives its potential from a voltage source 48 through plate resistor 50. Likewise, plate 28 of tube 24 receives its potential from the same source 48 through a resistor 52. Screen grids 34 and 36 are tied together and are also supplied by the same voltage source 48. Plate 26 is connected by a coupling resistor 54, in parallel with a coupling capacitance 56 to grid 40 of tube 24. Likewise, plate 28 of tube 24 is connected by a coupling resistor 58

having a capacitance 60 in parallel therewith to the control grid 38 of tube 22. A voltage divider 62 is connected across the voltage source 48, and a single tap is connected therefrom to common connecting means 46. A biasing resistor 64 is connected between grid 38 of tube 22 and the negative end of voltage source 48. Another biasing resistor 66 is connected between control grid 40 of tube 24 and the negative end of voltage source 48. One input terminal 63 is connected to suppressor grids 30 and 32, and the other input terminal 65 is connected to the common conducting means 46. One output terminal 67 is taken from said connecting means 46 while the other output terminal 69 is taken from plate 28 of tube 24.

The values of plate resistances 50, 52, bias resistors 64, 66 and coupling resistors 54, 58 are not critical. However said coupling resistors and said bias resistors may be appreciably larger than said plate resistors, and usually may be equal to one another.

The size of coupling capacitances 56 and 60 may be such that the time taken by them to charge or discharge from an equilibrium value of voltage to the other value is large in comparison with the duration of the triggering pulse but small in comparison with the time between successive pulses. Condensers of 50 m. m. f. capacitance are satisfactory.

The circuit is sensitive to triggering voltage of either polarity. Of course, reliable triggering necessitates the use of triggering pulses of very short duration. The operation of this circuit will be readily understood by those skilled in the art.

In Fig. 4, I show a simplified form of my invention which is particularly useful where amplitude variations in the frequency modulated wave are either not present or are of negligible value. Such a frequency modulated wave source is applied to a limiter 68 and then passed through a differentiating circuit 70 in the same manner as explained above. Now, however, differentiated pulses obtained from circuit 70 are applied directly to a "flip-flop" circuit 72 which in effect produces a translation of positive and negative pulses to unidirectional pulses. The circuit 72 may be merely an unbalanced trigger circuit wherein pulses of constant duration are initiated by single triggering pulses. Such a circuit may be triggered from one equilibrium state to another, but returns to the original equilibrium state after a short time interval thereby producing a series of pulses 73, Fig. 2, of a desired area each. The pulse output of the circuit 72 is applied to a low-pass filter 74 for integration, resulting in an audible output wave 21. The wide duration of the pulses 73 in contrast to the narrow pulses 18a are preferred since they present more power per pulse and thereby produce a smoother audible output.

In Fig. 5, I show a suitable "flip-flop" circuit which may be employed as the circuit 72. Such a circuit comprises two tubes 76 and 78 having respectively plates 80, 82, control grids 84, 86, and cathodes 88, 90, the latter being connected together. The plate 80 of tube 76 receives its potential from a voltage source 92 through plate resistor 94. The plate 82 receives its potential from the same source 92 through a plate resistor 96. The plate 80 of tube 76 is connected through a coupling resistor 98 to the grid 86 of tube 78. The plate 82 of the tube 78 is connected through a coupling condenser 100 to the grid 84 of tube 76. A voltage divider 102 is connected across

voltage source 92. A first tap 104 is connected from voltage divider 102 to cathodes 88, 90. A second tap 106 is connected from voltage divider 102 through a bias resistor 108 to the grid 84 of tube 76. Another bias resistor 110 is connected from grid 86 to the negative point of voltage source 92. One input terminal 101 is connected through a coupling capacitance 112 to grid 84 while the other input terminal 103 is connected to the negative end of voltage source 92. One output terminal 105 is connected to the positive end of voltage source 92 while the other output terminal 107 is connected to plate 82 of tube 78.

Unequal bias is used on the grids of the two tubes 76 and 78. The grid of one tube may have zero bias or a small positive bias, the flow of high grid current being prevented by the grid coupling resistor. The equilibrium of the circuit returns to its normal state after triggering since one of the plate coupling resistors normally provided in a circuit such as shown in Fig. 3 is herein eliminated, and a comparatively large value of coupling capacitance is used. The time interval of such a "flip-flop" circuit is determined principally by the magnitude of the resistor 108 and capacitance 100, and to a lesser extent, by the value of resistors 96, 98, and by the supply voltage 92.

The operation of the system shown in Fig. 4 is very similar to that shown in Fig. 1 except that the trigger circuit 14, the differentiating circuit 16 and the clipping circuit 18 of Fig. 1 is replaced in Fig. 4 by the multi-vibrator circuit 72. The output pulses 73 of the circuit 72 are approximately rectangular in shape, and substantially constant in duration and area. These pulses occur at the beginning of each positive half cycle of the input signal. It will be necessary, of course, that the time constants of the circuit be so adjusted that the pulse duration be less than the duration of one half cycle of the highest line frequency to be received.

It will be clear from the foregoing description that the "flip-flop" circuit 72 may be substituted for the rectifier 18 in the system of Fig. 1. Such a substitution will result in the production, in place of the narrow width pulses 18a, of the wider constant area pulses 73.

Although I have shown and described two different embodiments of my invention I am fully aware that many modifications thereof are possible. If the frequency of the incoming signal is undesirably high, it may be preferable to reduce the frequency thereof by heterodyning of the input prior to the "flip-flop" circuit operation. It will also be understood that the individual components illustrated and described herein are merely given by way of illustration and are not to be regarded as limiting the scope of the appended claims.

What I claim is:

1. A method of demodulating a frequency modulated wave comprising clipping the wave to produce a wave of approximately rectangular form, differentiating the rectangular wave to produce alternate positive and negative pulses one each for each cycle of the wave, said pulses being displaced in accordance with the frequency modulation of said wave, translating said pulses into unidirectional pulses of substantially constant amplitude and substantially constant width, the unidirectional pulses varying in their repetition rate according to the frequency modulation of said wave, and integrating with respect to time

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the unidirectional pulses to produce an audible output wave.

2. A system comprising a frequency modulated wave source means to clip the waves of said wave source to produce a second wave of approximately rectangularly pulsed form, means to differentiate the second wave to produce alternate positive and negative narrow width pulses one each for each half cycle of the second wave, said pulses being displaced in accordance with the frequency modulation of said wave source, means to translate said pulses into unidirectional pulses of substantially constant amplitude and substantially constant width, the unidirectional pulses varying in their repetition rate according to the frequency modulation of said wave, and means to integrate with respect to time said unidirectional pulses to produce an audible output wave.

3. The system defined in claim 2 wherein the translating means include a circuit having one mode of stability so that when it is triggered from one state of operation to another it will return to the first-mentioned state of operation after a predetermined interval, whereby pulses of a predetermined constant width can be produced which when integrated with respect to time produce a smooth audible signal.

4. The system defined in claim 2 wherein the translating means include a triggering circuit operable in response to the alternate positive and negative pulses to be triggered by one of the pulses from one state of operation to another and to be triggered back again by the next succeeding pulse thereby producing a second rectangular wave the side slopes of which are substantially vertical, means to differentiate said second rectangular wave to produce alternate positive and negative pulses, and means to rectify the last-named pulses.

5. The method defined in claim 1 wherein the translating of the alternate positive and negative

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pulses into unidirectional pulses comprises producing a second rectangular wave having substantially vertical side slopes, a fixed and constant wave amplitude, and a recurrence frequency equal to that of the frequency modulated wave, differentiating said second rectangular wave to produce alternate positive and negative pulses, and rectifying these pulses to produce said unidirectional pulses.

6. The method as defined in claim 1 wherein the translating of the alternate positive and negative pulses into unidirectional pulses comprises producing a second rectangular wave, the sides of each half cycle thereof being substantially vertical, differentiating said second rectangular wave to produce alternate positive and negative pulses of constant amplitude, and producing therefrom constant width pulses the duration of which is controlled.

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