

April 8, 1941.

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2,237,522

FREQUENCY MODULATION

Filed May 12, 1939

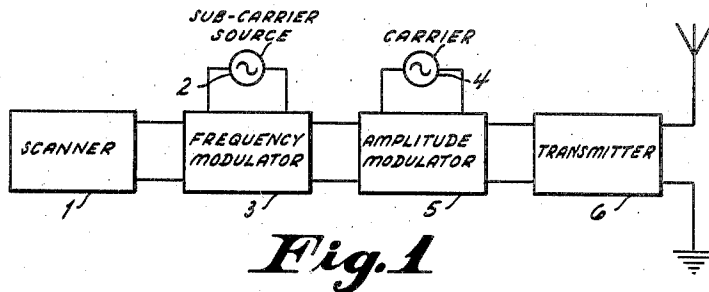


Fig. 1

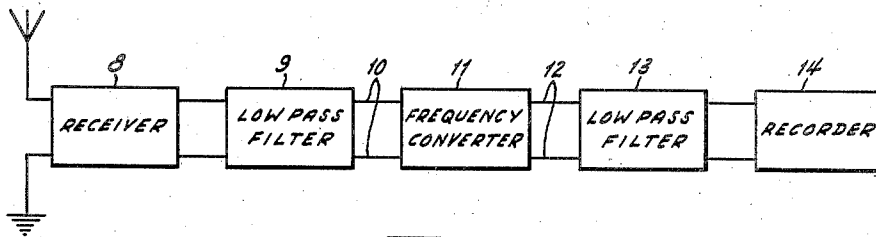


Fig. 2

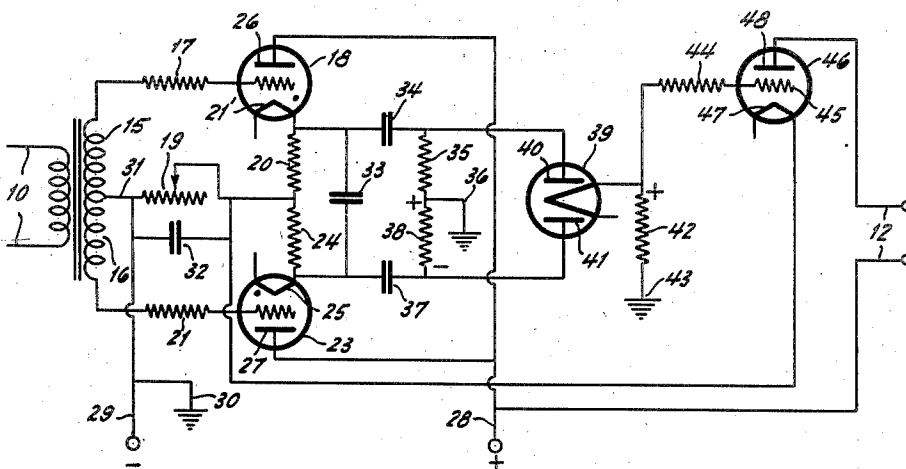


Fig. 3

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2,237,522

FREQUENCY MODULATION

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Application May 12, 1939, Serial No. 273,175

8 Claims. (Cl. 250—27)

This invention relates to signal transmission and more particularly to frequency demodulators for use in signaling systems in which the signal at the transmitter varies the frequency of an oscillator instead of its amplitude. The oscillator referred to is usually a generator of a sub-carrier frequency which amplitude-modulates a radio frequency carrier.

In the prior art receivers for frequency-modulated carriers it has usually been the practice to convert the frequency modulation into amplitude modulation by filter action. That is, the frequency demodulator is a filter whose voltage attenuation varies approximately linearly over the frequency range used in the modulation.

The filter type of frequency demodulator places certain requirements on the apparatus associated therewith. For example, the frequency input to the filter must be quite free of amplitude variations so that the output amplitude will be a function solely of the input frequency. Also, the input frequency to the filter demodulation should be virtually a pure sine wave since the higher frequency components present in a distorted wave may fall within the useful portion of the filter characteristic and influence the demodulated output adversely. These requirements can be met with suitable design of apparatus but in my invention I avoid this difficulty by use of an entirely different type of demodulator.

It is one object of my invention to produce a frequency demodulator that is independent of any amplitude modulation of the sub-carrier frequency.

Another object is to produce a frequency demodulator that requires no amplitude limiters or automatic gain control devices in any part of the receiving system.

Another object is to produce a frequency demodulator in which the output is related absolutely linearly to the input frequency.

Another object of my invention is to produce a frequency demodulator that will respond only to the fundamental component of the sub-carrier frequency, regardless of distortion of the wave shape of this frequency.

Another object is to produce a frequency demodulator in which square wave keying can be used for the sub-carrier frequency.

Other objects will appear in the following description, reference being had to the drawing in which—

Fig. 1 is a block diagram of a transmitter with which my frequency demodulator may be used.

Fig. 2 is a block diagram of the receiver containing my demodulator as a unit thereof.

Fig. 3 is a diagrammatic illustration of the circuit of the demodulator.

Referring to the drawing, the picture scanner or other signaling device varies the frequency

of a generator 2 to produce a sub-carrier of low frequency. For example, a suitable band for facsimile transmission has a range of 1600 to 2000 cycles per second but various other bands either above or below this may be used with like results. The method by which the sub-carrier frequency is varied to produce the modulation is immaterial as far as my invention is concerned and it is not described in detail, but it may be produced, for example, by the particular arrangement disclosed in my joint application with James E. Smith and James N. Whitaker, Serial No. 270,332, filed April 27, 1939. The output of the frequency modulator 3 will be used to amplitude-modulate the radio frequency carrier of the generator 4. This modulation may be obtained by any of the well known methods and the details need not be described. The output of the modulator 5 is passed to the transmitter 6, which may be of any desired construction and the signal is radiated by any suitable antenna.

In the receiving apparatus of Fig. 2 the signal is received on the antenna 7 and is amplified, detected and further amplified at 8. The output of receiver 8 is passed through low pass filter 9 which in this case may have an upper limit of slightly above 2000 cycles, but this may be omitted when the sub-carrier frequency chosen is in the order of 120 to 200 cycles. The output lines 10 of low pass filter 9 are connected to my improved frequency demodulator or converter 11 for changing the frequency modulations into amplitude modulations. The output lines 12 of the demodulator are connected to another low pass filter 13 which with the band given as an example would have an upper limit of less than 1600 cycles per second so as to spread the effect of the constant amplitude pulses of demodulator 11 over the complete cycle.

The output of the low pass filter 13 passes into recorder 14. The receiving apparatus 8, low pass filters 9 and 13 and the recorder 14 may be any of the well known constructions and the details are not disclosed as they are not necessary for an understanding of my invention.

The details of the frequency demodulator 11 are shown in Fig. 3. In this figure the input lines 10 are connected to the primary of a transformer, the secondary of which has sections 15 and 16. Section 15 of the secondary has one terminal connected through resistance 17 to the grid of a Thyatron or grid controlled gas tube 18. The other terminal of this secondary is connected through resistance 19 and resistance 20 to the cathode 21' of tube 18. The secondary 16 has one terminal connected through resistance 21 to the grid of a Thyatron tube 23 and its other terminal connected through resistance 19 and resistance 24 to cathode 25 of tube 23.

The secondary 15, 16, is arranged to feed the

grid circuits of the two Thyatron tubes in phase opposition as in an ordinary push-pull circuit.

The anode 26 of Thyatron tube 18 and the anode 27 of Thyatron tube 23 are connected in parallel to the positive terminal 28. The negative terminal 29 of the supply source is grounded at 30 and is connected to the mid-terminal connection 31 of the transformer as shown. Filter condenser 32 may be connected across the resistance 19.

The commutating condenser 33 is connected across points in the circuits of the two Thyatron tubes for extinguishing one tube when the other one fires. This condenser and its circuit should have a time constant of such value that the positive ions in the gas tube will diffuse and permit the grid to assume control before the condenser is able to discharge sufficiently to lower the cathode voltage below the anode voltage.

The cathode 21' of tube 18 is connected through condenser 34 and resistance 35 to ground at 36, and the cathode 25 of tube 23 is similarly connected through condenser 37 and resistance 38 to ground at 36. These two condensers and their associated resistances should form circuits having a sufficiently short time constant to permit them to charge or discharge completely within a half cycle of the highest frequency of the varying sub-carrier.

Double rectifier 39 has one anode 40 connected to the ungrounded end of resistance 35 and the other anode 41 connected to the ungrounded end of resistance 38. The cathode of this rectifier is connected through resistance 42 to ground at 43. This cathode is also connected through resistance 44 to grid 45 of tube 46 which serves to amplify the output of the rectifier 39. The cathode 47 of this tube is connected to the junction point of resistance 19 with the resistances 20 and 24, and the anode 48 is connected to one output terminal 12, the other output terminal 12 being connected to positive terminal 28 of the source of supply.

The operation will now be described.

The scanner 1 of Fig. 1 will produce a variable amplitude output and this varies the frequency of the sub-carrier source 2. The varying frequency output of source 2 covering a band, as assumed, 1600 cycles to 2000 cycles, passes into modulator 5 and the amplitude of the radio frequency carrier of generator 4 is modulated by this varying sub-carrier frequency. The output of the modulator 5 passes to the transmitting apparatus 6 and is radiated.

At the distant receiver the antenna 7 intercepts the modulated radio frequency carrier wave and this is amplified and detected to extract the sub-carrier frequency and is further amplified. The sub-carrier of course has the modulations of the signal in its varying frequency and it in most cases will also contain undesired amplitude modulations imposed by varying conductivity of the upper ionosphere. The varying sub-carrier frequency may also contain higher frequency components from other causes. The latter are removed by the low pass filter 9.

The output of the low pass filter is introduced into the transformer secondaries 15, 16, and on account of their connection in the way described, the grids of gas tubes 18 and 23 will be alternately positive and negative. If, for any given instant we assume that gas tube 23 is conducting, commutating condenser 33 will be charged by the voltage drop in resistance 24, the lower end of the condenser being positive, as shown in Fig. 3.

When the upper end of secondary 15 next becomes positive and the lower end negative, tube 18 will fire but the negative potential on the grid cannot extinguish tube 23 since the grid lost control because of the space charge of the free positive ions in that tube. However, as soon as gas tube 18 strikes, the negative end of commutating condenser 33, and therefore its positive end also, is raised by the amount of the voltage drop in resistance 20, and this voltage drop is greater than the internal plate-cathode drop of gas tube 23. Since condenser 33 cannot discharge quickly because of the value of its time constant, cathode 25 assumes a voltage higher than anode 27 and tube 23 is extinguished.

The cathode is held above the voltage of plate 27 for such length of time that the positive ions diffuse from around the grid but the negative potential of the grid prevents the tube from striking on this negative half cycle. Condenser 34 now starts to charge and condenser 37 to discharge. The charging current extends from 28 to the anode 26, cathode 21', condenser 34, resistance 35 and ground 36 and thence to the negative terminal 29. Condenser 37 discharges through resistances 24, 19 and 38. These two condensers and their circuits have such time constants that they charge or discharge fully within a half cycle of the highest frequency used in the sub-carrier frequency modulation. When condenser 34 charges in the way just described rectifier 39 places a positive pulsating potential across resistance 42 due to charging current from anode 40 to ground terminal 43. The drop in resistance 38 from discharge of condenser 37 places a negative potential on rectifier plate 41. No current of course can flow through this half of the rectifier for this part of the cycle.

For the next half cycle gas tube 23 will strike and gas tube 18 will be extinguished by the action of commutating condenser 33 which need not be further described. As condenser 37 recharges, rectified current will pass through resistance 42 to ground in the way previously referred to, but the potential produced in resistance 35 from discharge of condenser 34 will not send current through the rectifier.

From the described operation it will be apparent that two pulses will pass through load resistance 42 for each complete cycle of the sub-carrier frequency in the input transformer. By proper amplification of the signal before demodulation the Thyatron tubes can be made to operate on a very weak signal such as in a severe fade. The current pulses passing through resistance 42 will be of constant amplitude. In other words, the potential drop in resistance 42 for each pulse will be independent of the signal strength. The average current in resistance 42 is, however, dependent directly upon the number of pulses per second. The greater the number of pulses per second the higher will be the average current in this resistance. The pulsating output of tube 46 will be smoothed out by filter 13 and the voltage of the input of recorder 14 will vary in amplitude with the varying frequency of the input of the demodulator. Since the output is independent of varying amplitude in the input that may have been produced by fading conditions or by any other cause no voltage limiters are required anywhere in the receiving system. The demodulator inherently acts as a limiter in its conversion of the frequency variations into amplitude variations. The amplitude modulations produced by fading conditions are thus eliminated. At the

same time the demodulator overcomes all the difficulties of the filter type used in the prior art as previously referred to herein.

Instead of low pass filters in the receiving system I may use band pass filters and various other additions and substitutions of devices well known in the art may be made in either the transmitting or receiving system without departing from the spirit of the invention.

The amplifier 46 may be omitted and filter 13 connected directly to resistance 42 and the action will be the same. Also, it is permissible to use only one of the condensers 34 and 37. This would halve the number of rectified pulses in the output of the demodulator but the same results could be obtained as with two condensers.

In disclosing the transmitting and receiving system with which my invention is used, I have described only those that are essential for a clear understanding of the invention. It will be apparent that in the commercial installation many other well known devices will be used for improved operation of the system as a whole, but these do not affect the operation of the demodulator to which my invention relates.

Having described my invention, what I claim is:

1. In a demodulator for a frequency modulated carrier wave, means for receiving the frequency modulated carrier wave, means for storing a predetermined quantity of electrical energy during each half cycle of the carrier wave and discharging it during the succeeding half cycle, means for rectifying a constant fractional part of the energy thus passing through said first mentioned means and an indicator operated by the rectified energy.

2. In a demodulator for a frequency modulated carrier wave, means for receiving the frequency modulated carrier wave, means for storing a predetermined quantity of electrical energy during each half cycle of the carrier wave and discharging it during the succeeding half cycle, means for rectifying a constant fractional part of the energy passing in one direction through the first mentioned means and an indicator operated by the rectified energy.

3. In a demodulator for a frequency modulated carrier wave, means for receiving the frequency modulated carrier wave, a pair of condensers, means for charging one condenser to a predetermined constant potential on the positive half cycles of the carrier wave and discharging it on the negative half cycles, means for charging the other condenser to a predetermined constant potential on the negative half cycles and discharging it on the positive half cycles, means for rectifying a constant fractional part of the current passing through said condensers and an indicator operated by the rectified energy.

4. In a demodulator for a frequency modulated carrier wave, means for receiving the frequency modulated carrier wave, a pair of condensers, means for charging one condenser to a predetermined constant potential on the positive half cycles of the carrier wave and discharging it on the negative half cycles, means for charging the other condenser to a predetermined constant potential on the negative half cycles and discharging it on the positive half cycles, means for rectifying a constant fractional part of the current passing through said condensers, a filter

for smoothing the rectified current, and an indicator operated by the rectified current.

5. In a demodulator for a frequency modulated carrier wave, means for receiving the frequency modulated carrier wave, a pair of condensers, a pair of resistances, means for charging one condenser to a predetermined constant potential on the positive half cycles of the carrier wave and discharging it through one resistance on the negative half cycles, means for charging the other condenser to a predetermined constant potential on the negative half cycles and discharging it through the other resistance on the positive half cycles, a rectifier connected around each resistance and an indicator operated by the current passing through the rectifiers.

6. In a demodulator for a frequency modulated carrier wave, means for receiving the frequency modulated carrier wave, a pair of condensers, a pair of resistances, means for charging one condenser to a predetermined constant potential on the positive half cycles of the carrier wave and discharging it through one resistance on the negative half cycles, means for charging the other condenser to a predetermined constant potential on the negative half cycles and discharging it through the other resistance on the positive half cycles, a rectifier connected around each resistance, a filter connected to the rectifiers and an indicator operated by the current passing through the filter.

7. In a demodulator for a frequency modulated carrier wave, means for receiving the frequency modulated carrier wave, a pair of gas tubes each having a cathode, a control electrode, and an anode, a signal input source connected to the control electrode and cathode of the tubes in phase opposition to fire each tube alternately and on alternate half cycles, means to extinguish one gas tube on one-half cycle when the other fires on the other half cycle, a condenser, means connected to said tubes for charging the last mentioned condenser to a predetermined constant value on one-half wave of the carrier wave and to discharge it on the succeeding half wave, means for rectifying a constant fractional part of the alternating current passing through the last mentioned condenser and indicating means responsive to the average value of said rectified current.

8. In a demodulator for a frequency modulated carrier wave, means for receiving the frequency modulated carrier wave, a pair of gas tubes each having a cathode, a control electrode and an anode, a signal input source connected to the control electrode and cathode of the tubes in phase opposition to fire each tube alternately and on alternate half cycles, means to extinguish one gas tube on one-half cycle when the other fires on the other half cycle, a condenser, means connected to said tubes for charging the last mentioned condenser to a predetermined constant value on one-half wave of the carrier wave and to discharge it on the succeeding half wave, means for rectifying a constant fractional part of the alternating current passing through the last mentioned condenser, means to integrate the rectified pulses and indicating means responsive to the output of the integrating means.

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