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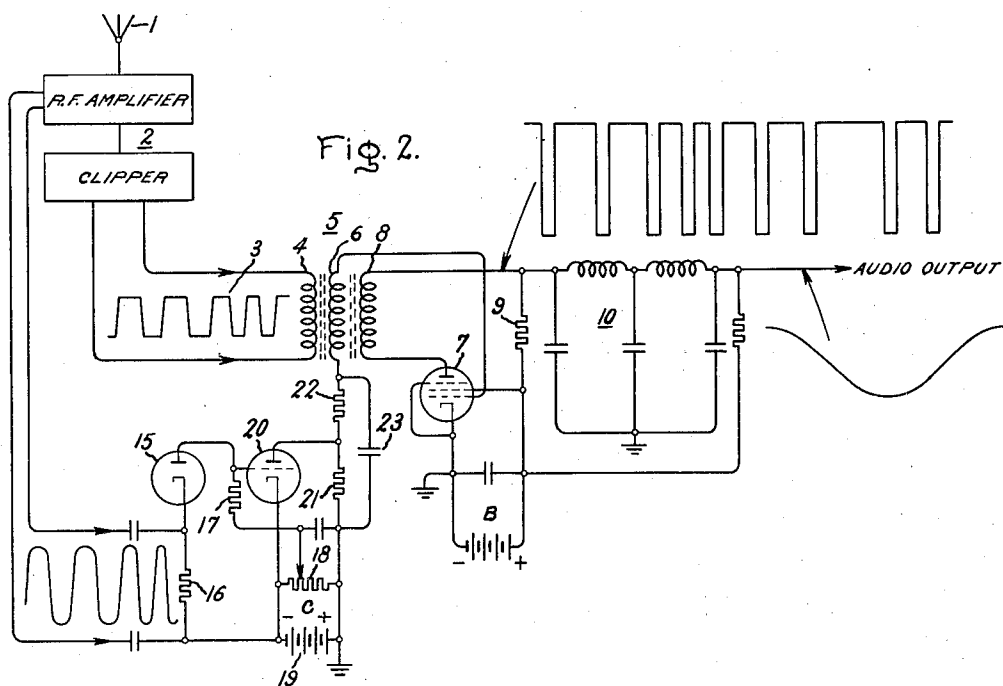
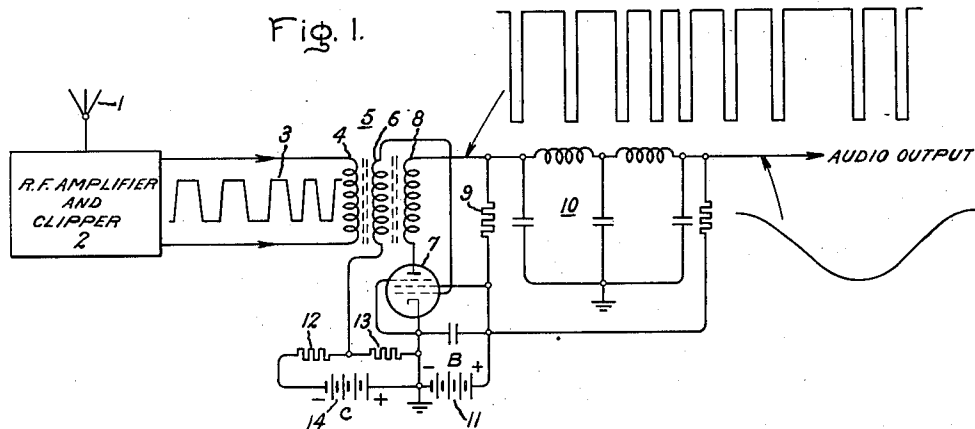
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2,484,556

DEMODULATOR FOR FREQUENCY MODULATED SIGNALS

Filed Nov. 12, 1946

2 Sheets-Sheet 1



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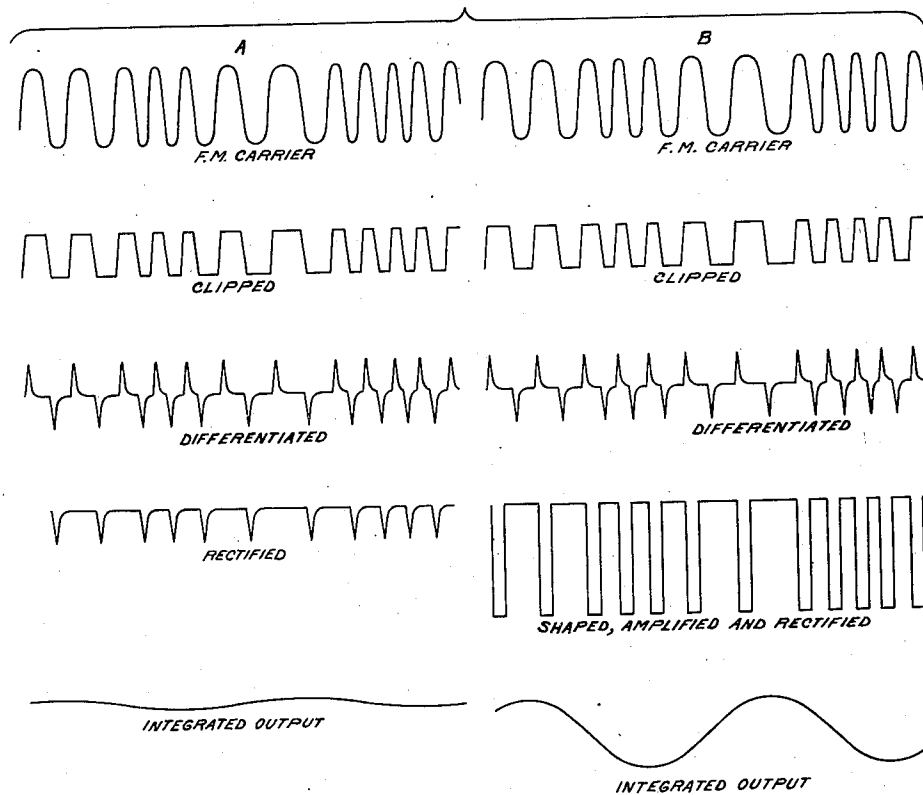
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2 Sheets-Sheet 2

Fig. 3.



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DEMODULATOR FOR FREQUENCY MODULATED SIGNALS

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1 Claim. (Cl. 250-27)

1

My invention relates to an improved counter type demodulator for frequency or phase modulated signals.

An object of my invention is to provide a demodulating device for frequency or phase modulated signals which will provide a high output signal level.

A further object is to provide a demodulating device incorporating means for preventing the passage of noise impulses in the absence of a received carrier of at least a predetermined intensity.

Another object of my invention is to provide a demodulator for phase or frequency modulated signals with high signal-to-noise level characteristics.

An additional object is to eliminate the necessity for high gain output amplifiers in a phase or frequency modulation receiver and thereby reduce the distortion and noise level.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the accompanying drawings, in which Fig. 1 is a diagram of demodulator apparatus embodying the invention; Fig. 2 is a diagram of a demodulator incorporating a squelch circuit; and Fig. 3 is an explanatory diagram illustrative of the operation of the apparatus.

Counter type demodulators have been known in the past wherein a frequency-modulated carrier wave is successively subjected to clipping, amplification and differentiation to produce a series of short pulses, which in turn are rectified and integrated to produce a demodulated audio output signal. The output signal of a demodulator of this type, however, is of relatively low intensity and must be amplified in high gain voltage amplifiers which may introduce undesired noise and distortion.

The demodulator, according to my invention, provides a relatively high intensity output signal permitting the use of amplifiers of low gain resulting in an output signal characterized by the presence of a minimum of noise and distortion.

According to my invention, the frequency-modulated carrier wave is clipped, as in the prior art, and is then applied to one winding of a three-winding transformer in which differentiation of the clipped wave occurs. The differentia-

2

tion in this transformer provides very sharp pulses, as hereinafter described. Associated with the transformer is an electron discharge device operating as a self-saturating amplifier to generate a steep-sided square pulse in response to each positive-going differentiated pulse, each square pulse being much larger than the corresponding initiating differentiated pulse and therefore representing more energy. The amplifier drives itself to complete saturation during each pulse and provides substantially perfect limiting of each pulse. The electron discharge device also serves as a rectifier for the square pulses and feeds the rectified pulses to a low pass filter, such as an audio pass filter, in which integration is obtained to produce an output signal which is determined by the rate at which the square pulses are applied to the filter. The filter output therefore is a reproduction of the original modulation of the incoming carrier.

In the circuit shown in Fig. 1, antenna 1 furnishes frequency, or phase, modulated carrier signal energy to a radio frequency amplifier and clipper circuit 2, wherein the incoming signal is modified from a sine wave, such as that labelled "FM carrier" in Fig. 3, to a clipped sine wave as shown at 3 in Fig. 1 and labelled "Clipped" in Fig. 3. The clipped wave is applied to winding 4 of a three winding transformer 5, which is preferably of the powdered iron core type. The positive-going leading edge of each clipped pulse as it reaches winding 4 induces a positive potential in the form of a sharp differentiated pulse at the top of the secondary winding 6 of transformer 5 to drive the control electrode of electron discharge device 7 sharply positive. The resultant conduction of device 7 causes increasing anode current flow in the third transformer winding 8, the direction of the windings being so chosen that the increase in anode current induces an even more positive potential at the control electrode end of winding 6. This feedback action quickly drives device 7 to anode current saturation. The device remains saturated for a predetermined time during which a maximum voltage drop occurs across load resistor 9 providing a shaped, amplified and rectified pulse as shown in Fig. 3 for each leading edge of the clipped signal. The duration of saturation is established by the time constants as determined by the values of resistance, inductance and distributed capacity of the circuits including the transformer windings and components connected therewith. The control electrode of device 7 may be driven, during this time, more positive

than the potential required for anode current saturation. When the control electrode potential decays, as the charge accumulated in the distributed capacity leaks off, the control electrode starts to fall below the saturation potential and the anode current starts to decrease. A negative-going potential is thus induced on the control electrode end of winding 6 which serves to hasten cut-off of device 7. The negative-going portions of the differentiated pulses, formed by the lagging edges of the clipped carrier waves, do not operate device 7. The device operates, therefore, as a rectifier.

The circuit including the transformer and device 7 accordingly operates in response to the leading edge of each clipped sine wave to provide a positive-going differentiated pulse, which is generated by induction in winding 6 by the current in winding 4. These positive-going differentiated pulses initiate negative-going voltage pulses across load resistor 9 of large constant magnitude due to the self-saturation of device 7.

The negative-going pulses generated by device 7 are integrated by filter network 19, which resonates at a frequency below the frequency of pulse repetition, such as at less than 250 kilocycles, and the resultant output voltage, which may be an audio frequency voltage, represents a summation of the energy contained in the square wave rectified pulses. The output voltage is, accordingly, an accurate reproduction of the frequency, or phase, modulation appearing on the received carrier.

Operating potentials may be supplied for device 7 in a conventional manner, anode power being provided from a suitable direct current potential source such as B battery 11 and control electrode negative bias potential from a voltage divider comprising resistors 12 and 13 connected across C battery 14. A conventionally excited heater for the cathode of device 7 is also provided though not shown in the drawing.

The advantages of demodulation as described above over the prior art methods are immediately apparent from Fig. 3, wherein the curves under "A" indicate prior art operation, and those under "B" are exemplary of operation utilizing the device of Fig. 1. In the prior art, as shown, the positive differentiated pulses formed by the leading edges of clipped input signals waves are rectified directly. These rectified pulses contain only small quantities of energy, being a little less than the energy in the positive differentiated pulses. Not only are the rectified pulses inadequately limited for many applications, since the rectified pulse energy is related to the energy in the corresponding differentiated pulse, but the low intensity of the rectified pulses requires high gain amplification to obtain useable output signal strength as indicated by the low intensity output wave shown in Fig. 3.

On the other hand, according to the present invention, the differentiated pulses initiate the generation of almost perfectly limited square pulses not dependent in energy content on the quantity of energy in the differentiated pulses. The resultant output signal derived from integration of the square pulses contains fewer undesired (noise) components and is of increased intensity reducing the requirements as to gain in the remainder of the apparatus.

The demodulator shown in Fig. 2 comprises a radio frequency amplifier and clipper, indicated by numeral 2, for furnishing clipped frequency, or phase, modulated sine waves 3 to primary wind-

ing 4 of transformer 5. Winding 6 is arranged to provide positive differentiated pulses to the control electrode of discharge device 7 in response to the leading edges of the clipped sine waves, and feedback action from winding 8 to winding 6 causes device 7 to reach anode current saturation very quickly for each positive differentiated pulse appearing on winding 6 as explained in connection with Fig. 1. Filter network 10 integrates the substantially square wave voltage appearing across load resistor 9 to provide an output signal corresponding to the frequency modulation of the carrier received on antenna 1.

In addition to the elements described above which are substantially the same as those of Fig. 1, the device shown in Fig. 2 incorporates a squelch circuit arranged to provide a strong negative cut-off bias to the control electrode of device 7 in the absence of a received carrier of greater than a predetermined minimum intensity. The squelch circuit comprises a diode discharge device 15 with a cathode resistor 16 connected to receive the amplified but unclipped carrier signal from the radio frequency amplifier section of amplifier and clipper circuit 2. When a strong carrier is received, discharge device 15 conducts, drawing anode current through resistor 17 to produce a negative potential on the anode. A threshold potential for conduction of device 15 is established by selecting the position of the slider of potentiometer 18, which is arranged as a voltage divider across a negative bias potential source 19 indicated as a C battery.

Electron discharge device 20 is arranged to be conductive when no strong carrier is being received. Power source 19 serves to provide operating potentials for device 20, the negative terminal being connected to the cathode, the positive (grounded) terminal to the anode, and a selected intermediate potential from the slider of potentiometer 18 to the control electrode.

In the absence of a strong carrier, diode device 15 is non-conductive and there is substantially no voltage drop in resistor 17. The control electrode of device 20 is thus maintained at a positive potential with respect to the cathode, as determined by the adjustment of the slider of potentiometer 18, and device 20 conducts to produce a strongly negative potential with respect to ground on that end of resistor 21 which is connected to the anode of device 20. This negative potential, which may be as high as 100 volts or more, biases the control electrode of device 7 far beyond cutoff preventing the operation of the device in response to any noise impulses which may be received on the antenna 1 or otherwise.

When a carrier is received which is strong enough after rectification by diode device 15 to produce sufficient voltage drop in resistor 17 to overcome the positive bias on the control electrode of device 20, device 20 is cut off, conduction through resistor 21 ceases and the control electrode of device 7 is made self-biasing through resistors 21 and 22. Condenser 23 functions as storage condenser to prevent rapid fluctuations in the potential of the control electrode of device 7.

While I have shown only certain preferred embodiments of my invention by way of illustration, many modifications will occur to those skilled in the art and I therefore wish to have it understood that I intend in the appended claim to cover all such modifications as fall within the true spirit and scope of my invention.

5

What I claim as new and desire to secure by Letters Patent of the United States is:

A demodulator for frequency modulated clipped carrier wave signals comprising a transformer, said transformer having an output winding and a feedback winding, an electron discharge device having a control electrode, an anode, a screen electrode and a cathode, a source of operating potential having a positive terminal and a negative terminal, the negative terminal being connected to said cathode, one end of said output winding being connected through an impedance to said positive terminal and the other end of said output winding being connected to anode, said feedback winding being connected in regenerative polarity at one end to said control electrode and at the other end through a control electrode leak resistor to said cathode, means to impress said signals on said control electrode to drive said device to anode current saturation in response to impression on said control electrode of the positive-going portion of each cycle of said signal thereby to produce current pulses in said anode circuit, a low pass filter connected between said

6

one end of said output winding and a point at fixed potential with respect to one of said terminals thereby to integrate the pulses appearing across said impedance, said filter comprising means for passing desired demodulation products to an output terminal, and means to impress from said positive terminal a substantially constant positive potential on said screen electrode thereby to minimize the effect of voltages appearing in the input portion of said filter on the amplitude and duration of said anode current pulses.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,113,214	Luck	Apr. 5, 1938
2,261,643	Brown	Nov. 4, 1941
2,358,297	Bedford	Sept. 19, 1944
2,441,957	DeRosa	May 25, 1948