

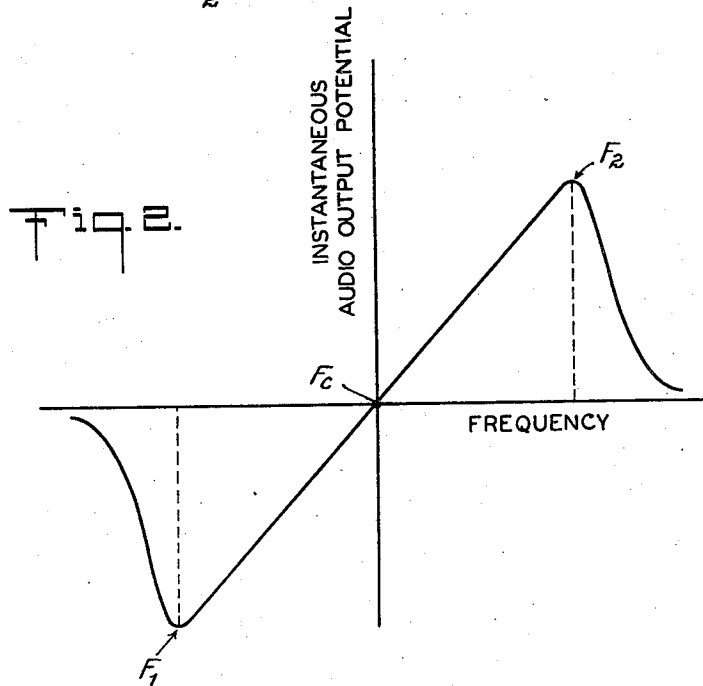
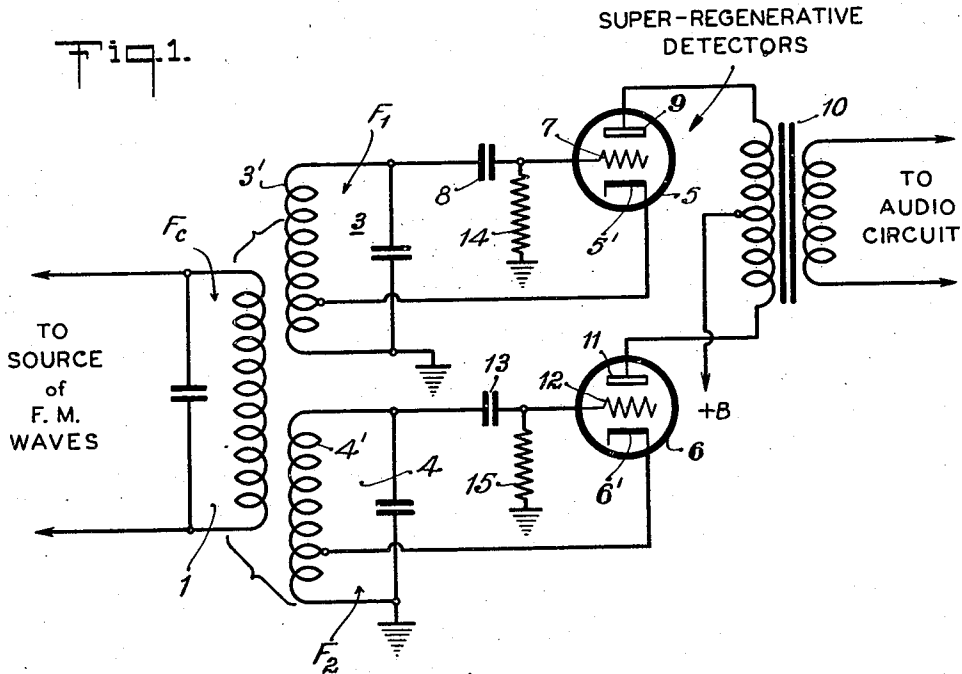
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G. C. SZIKLAI

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FREQUENCY MODULATION DETECTOR

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INVENTOR
GEORGE C. SZIKLAI
BY *H.S. Brown*
ATTORNEY

UNITED STATES PATENT OFFICE

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FREQUENCY MODULATION DETECTOR

George C. Sziklai, Princeton, N. J., assignor to
Radio Corporation of America, a corporation of
Delaware

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My present invention relates to demodulators of angular velocity-modulated carrier waves, and more especially to a highly sensitive balanced detector which is essentially non-sensitive to amplitude changes of the modulated carrier energy.

In his U. S. Patent No. 2,273,090, granted February 17, 1942, M. G. Crosby has disclosed and claimed limiter networks for receivers of angular velocity-modulated carrier wave energy. The limiters disclosed in that patent are amplifier circuits utilizing super-regeneration to effect substantially complete elimination of amplitude modulation effects of the received carrier energy. Since the functioning of the super-regeneration limiters of the said Crosby patent is fully described therein, it is sufficient for this application to point out that the limiter action is generally due to the following: The modulated signal which is to be limited is applied to a super-regenerative amplifier, and the radio frequency energy built up by the super-regenerative effect is employed as the limited signal. The radio frequency oscillations built up are not detected within the super-regenerative tube, but are passed on as radio frequency energy. This energy consists of pulses of oscillations which appear once per cycle of the quench frequency. The pulses are passed through a following selective circuit to be smoothed out so that the quench frequency does not appear in the output energy fed to a subsequent discriminator-rectifier.

Now, I have discovered that an additional function can be derived from the super-regenerative limiter circuit of the Crosby type. In addition to securing elimination of amplitude changes of the received carrier, the same circuit, with a simple and economical change, can be made to act as a highly sensitive and selective demodulator.

Accordingly, it is one of the essential objects of my present invention to provide a balanced demodulator, insensitive to amplitude variations of the received carrier, which comprises a pair of super-regeneration detectors having the output circuits thereof in push-pull relation, and whose input circuits are oppositely mistuned relative to the center, or midband, frequency of the applied waves.

Another object of my present invention is to provide a pair of super-regenerative detectors of frequency modulated carrier wave energy (FM) which are concurrently limiters of amplitude modulation effects, thereby eliminating the need for a separate limiter stage.

Still, another object of my invention is to pro-

vide a pair of super-regenerative detectors with output circuits in push-pull relation, and whose input circuits are tuned apart in excess of the maximum frequency deviation of received FM waves.

Yet other objects of my invention are to improve and render more efficient detectors of FM waves, and more especially to provide FM detectors which are highly sensitive, selective and economical to manufacture and assemble.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims; the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description taken in connection with the drawing in which I have indicated diagrammatically a circuit organization whereby my invention may be carried into effect.

In the drawing:

Fig. 1 shows a circuit embodying the invention,

Fig. 2 shows the detection characteristic of the detector circuit.

Referring, now, to the accompanying drawing, the demodulation network of Fig. 1 may be employed in any desired type of receiver of angular velocity-modulated carrier waves. The term "angular velocity-modulated carrier wave" is generic in its scope, since it is equally applicable to FM, or phase modulated, carrier wave energy. The receiver may be of the superheterodyne type, and the demodulator will then function as the second detector. On the contrary, there could be used an antenna circuit capable of passing the entire 42 to 50 megacycle (mc.) band. In such case, an aperiodic amplifier would couple the antenna to the primary circuit of the demodulator input transformer. The invention is not restricted to the assigned FM band of 42-50 mc., since the circuit is operative at higher frequencies.

Regardless of the source of the FM wave energy, the latter is applied to the primary resonant circuit of the input transformer. The secondary resonant circuits, 3 and 4, are tuned to opposite sides of the frequency F_c of circuit 1. The frequency F_c , which is the center or mid-band frequency of the applied modulated waves, will be of the operating intermediate frequency (I. F.) value when the receiver is of the superheterodyne type. The frequencies F_1 and F_2 may be spaced apart by a frequency value exceeding the maximum frequency deviation of the carrier. In the assigned FM band the maximum frequency

deviation is 150 kilocycles (kc.). As is well known to those skilled in the art, the carrier is deviated in frequency by the modulation energy. The frequency deviation is proportional to the modulation amplitude, whereas the rate of deviation is a function of the modulation frequencies per se.

The electron discharge devices 5 and 6 are shown as triodes. However, they may be of any other desired construction. For example, the triodes may be mounted within a common tube envelope for purposes of economy. The cathode 5' of triode 5 is connected to an intermediate point on the coil 3' of circuit 3. The control grid 7 of triode 5 is connected through condenser 8 to the high potential side of circuit 3. The opposite side of the circuit is grounded. The plate 9 of triode 5 is connected to one side of the primary winding of audio output transformer 10.

The plate 11 of triode 6 is connected to the opposite end of the primary winding of transformer 10. The center point of the primary winding is connected to the positive terminal (+B) of the direct current energizing source. The cathode 6' of triode 6 is connected to a low potential tap on the coil 4' of input circuit 4. The grid 12 of triode 6 is connected through condenser 13 to the high potential side of input circuit 4, while the low potential side is at ground. Grid 7 is returned to ground through the grid leak resistor 14, while grid leak resistor 15 connects grid 12 to ground.

The secondary winding of audio output transformer 10 is connected to the input electrodes of a following amplifier, and the latter may be followed by one or more additional audio stages terminated by a reproducer of any well known type. Each of the condenser-resistor networks 8-14 and 13-15 is given a time constant such that super-regenerative action takes place in each of the detector stages.

It will be noted that each of the detector tubes is connected to function as a regenerative detector of the grid leak type. The time constant of each grid circuit is chosen so that super-audible quenching action takes place so as to provide the required super-regenerative effect. The relaxation rate (quenching period) may be chosen from 30,000 to 200,000 cycles per second. The smaller the quench frequency, the more total oscillation time and, therefore, more audio output is secured. It is not believed necessary, for the purposes of this application, to explain in detail the manner in which a self-quenching detector of the super-regenerative type operates. It is sufficient to point out that the regenerative action in each detector stage is permitted to build up to a point such that oscillation has commenced, the quenching action then preventing self-oscillation. This results in a highly sensitive type of detector with high gain simultaneously secured. By mistuning the input circuits 3 and 4 to opposite sides of the center frequency F_c , discrimination is secured. The detection characteristic is shown in Fig. 2. The opposite peak frequencies F_1 and F_2 are located at substantially the peaks of the S-shaped curve. The characteristic is substantially linear between the peak frequencies. "Frequency" as abscissae is plotted against "instantaneous audio output potential" as ordinates. The curve shows the conversion of FM signals into audio voltage.

As stated previously, this circuit eliminates the need for a special amplitude limiter stage prior to the detector input transformer. The present demodulator network provides substantially com-

plete elimination of amplitude modulation effects which may appear on the FM wave energy transmitted to the input transformer. The limiting function has been explained in the aforementioned Crosby patent, and reference is made to the said patent for a detailed explanation of the manner in which the limiting action is secured. Briefly, the super-regenerative limiting action is due to the limited grid voltage swing, which is provided by the grid current and cutoff points.

According to my present invention, demodulation is secured in addition to limiting. I have discovered that demodulation is readily secured from the limiting action provided in the aforesaid Crosby circuit, by means of an integrating action. It is to be understood that in the absence of received carrier energy, or where carrier energy is received which is not frequency modulated, the plate circuits of the detector tubes are balanced, and hence the output of the demodulator network will be zero. With varying frequency of the received carrier energy, the output of the demodulator network will follow the characteristic shown in Fig. 2. Since due to grid detection the plate current in each detector tube is limited, the output will be essentially free from audio components due to amplitude modulation.

In a self-quenched super-regenerative circuit the duration of the oscillation in the grid circuit will depend on the external carrier. The larger the carrier amplitude, the shorter will be the oscillation period. The amplitude of this oscillating voltage will depend on the circuit parameters only, and is practically independent of the external signal. The oscillating and relaxing voltage is rectified by the detector tube, and the output voltage is integrated by the reactance in the plate circuit. If, then, the signal is applied to a discriminator network, which develops two radio frequency voltages which are 180 degrees out of phase, at two different points, and varying in magnitude according to the frequency of the carrier, there will be produced a modulation signal voltage across transformer 10 which is identical to the signal originally frequency modulating the carrier. Demodulation takes place due to the non-linear characteristic of the tubes which rectify the radio frequency current produced in the super-regenerative circuit. Limiting action is due to the inherent property of super-regenerative circuits, i. e.: that only the duration of the radio frequency oscillation changes, but not the amplitude thereof.

The operation of a super-regenerative circuit differs somewhat from what of a simple detector circuit in the presence of signals of a varying frequency. In the case of the simple detector the output of the latter depends solely upon the voltage applied to the detector input, and not at all upon the frequency of this voltage. It is understood, of course, that the magnitude of this voltage will vary with frequency if the voltage is obtained by circuit resonance, but this is not a characteristic of the detector itself. In the case of a super-regenerative receiver, if the signal voltage is of the same frequency at the oscillations generated by the detector circuit in the absence of signal voltage, the detector output will depend to a greater or less extent upon the magnitude of the signal voltage according to circuit constants employed and adjustment thereof. However, if the applied signal has a frequency substantially different from the natural oscillation frequency of the detector, the resulting volt-

age input to the detector tube which is obtained by adding together the signal voltage and the locally-generated oscillation, will depend upon the frequency of the signal.

Thus, a detected output is possible from a super-regenerative detector in the presence of a variable frequency signal, even though the amplitude of this signal arriving at the input electrodes of the detector were perfectly constant. It is thus seen that the utilization of a super-regenerative detector system gives a result which is not merely the improvement in the sensitivity characteristic of the super-regenerative detector, but brings in the possibility of a limiting action without the necessity for any separate limiting device. The push-pull arrangement is not required to insure this result, but has the advantage that it provides a still further balance against amplitude variation effects, especially when the instantaneous signal frequency is at, or near, its mean frequency value so that it differs substantially equally from the natural oscillation frequencies of the two detector systems.

In place of the audio transformer 10, there may be employed resistance coupling. In that case, the resistors should be shunted with capacitors to bypass the radio frequency current and integrate the audio component. It will now be seen that I have provided a detector circuit for FM signals which is inherently non-sensitive for amplitude changes of the FM carrier. The detector employs a pair of balanced super-regenerative rectifiers working from a frequency discriminator which supplies radio frequency voltages 180 degrees out of phase. The rectifiers have a reactance in the output thereof to provide radio frequency by-passing and integration of the audio component.

While I have indicated and described a system for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organization shown and described, but that many modifications may be made without departing from the scope of my invention, as set forth in the appended claims.

What I claim is:

1. In combination, a pair of electron discharge devices, each device containing at least a cathode, a control grid and an output electrode, a frequency discriminatory input network coupled to the control grid of each of said devices, a common audio output circuit coupling the output electrodes of said devices, means providing oscillation-producing regenerative feed-back between the output electrode and control grid of each of said devices, and separate means connected in circuit between said network and each of the con-

trol grids for providing quenching of oscillations thereby to provide super-regenerative action.

2. In a combined limiter-demodulator network for signals of variable frequency, an oscillation generator tube having input and output electrodes coupled in an oscillatory circuit, a second oscillation generator tube having input and output electrodes coupled in an oscillatory circuit, means for energizing the electrodes of both tubes to provide oscillations of substantially constant amplitude, resistor-condenser means connected to the input electrode of each tube for interrupting said oscillations periodically, a common audio output circuit coupled to the output electrodes of said tubes, and a frequency discriminatory signal input network coupled to the input electrodes of said tubes.

3. A detector system for frequency modulated waves inherently non-sensitive for amplitude change of the carrier, comprising a pair of balanced self-quenching super-regenerative detectors of the grid leak type, a frequency discrimination wave input circuit coupled to the input electrode of each detector, a common audio output circuit connected to the output electrodes of the detectors, and a reactance in the audio output circuit to provide bypassing of radio frequency currents and integrating of the audio component.

4. In combination, a pair of super-regenerative rectifier tubes, each tube containing at least a cathode; a control grid and an output electrode, a common frequency discriminatory input network coupled to the control grid of each of said devices, a common audio output circuit coupling the output electrodes of said devices, condenser-resistor means connected to each of the control grids for providing quenching of oscillations thereby to provide super-regenerative action, and means providing regenerative feedback between the output electrode and control grid of each of said devices.

5. In a combined limiter-demodulator network for signals of variable frequency, a first tube having input and output electrodes coupled in a radio frequency oscillatory circuit, a second tube having input and output electrodes coupled in a second radio frequency oscillatory circuit, means for energizing the electrodes of both tubes to provide oscillations of substantially constant amplitude, condenser-resistor means for interrupting said oscillations periodically to provide super-regenerative action, a common audio output circuit coupled to the output electrodes of said tubes, and a common frequency discriminatory signal input network coupled to the input electrodes of said tubes.

GEORGE C. SZIKLAI.