

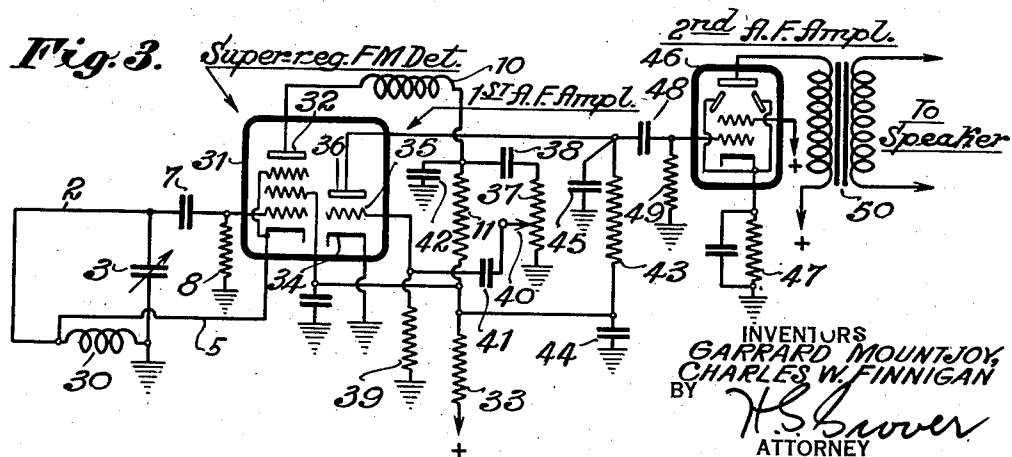
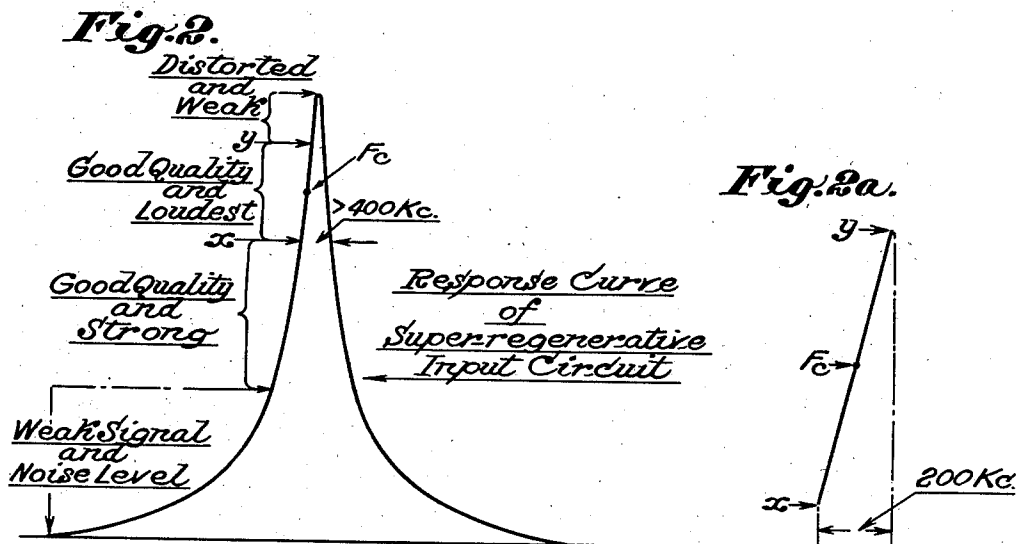
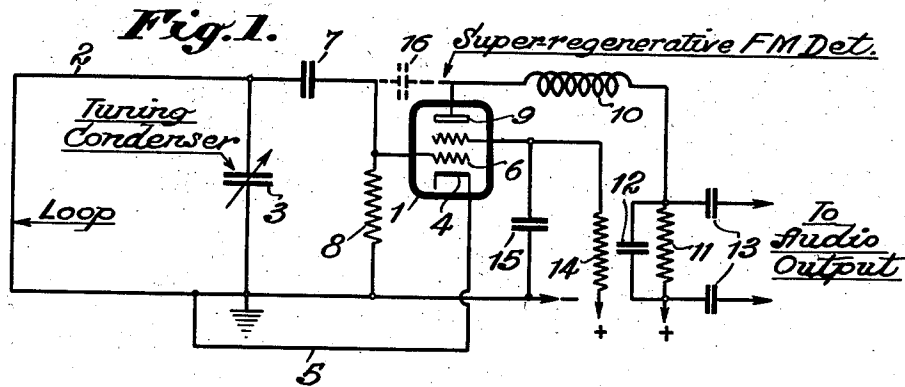
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SUPER-REGENERATIVE RECEIVER CIRCUIT

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SUPERREGENERATIVE RECEIVER CIRCUIT

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Our present invention relates to receiving systems for angular velocity-modulated carrier waves, and more particularly to super-regenerative receivers adapted to receive frequency modulated carrier waves.

One of the main objects of our present invention is to provide a super-regenerative detector circuit for angular velocity modulated carrier waves, wherein the detector has a signal collector input circuit of the tunable loop type which is sufficiently broad in pass band to pass efficiently waves having a high frequency deviation range.

Another highly important object of this invention is to provide a compact receiver of the super-regenerative type wherein the quench, or interruption, frequently is permitted to pass with demodulated signal energy from the super-regenerative detector to the first audio stage thereby to increase the volume output of the receiver, and the quench frequency being removed subsequent to the first audio stage.

Another important object of our invention is to provide a highly simplified and economical frequency modulated carrier wave (FM) receiver; the latter essentially comprising a super-regenerative detector tube having a tunable loop input circuit, and but one audio amplifier stage between the detector and reproducer.

Another object of our invention is to provide an FM receiver using a demodulator fed directly by a tunable loop circuit thereby avoiding the need for an amplitude limiter network prior to the demodulator; the receiver cabinet housing, in addition to the demodulator tube, an audio stage and a reproducer of the loudspeaker type.

Still other objects of our invention are to improve generally the simplicity and efficiency of FM receivers, and more especially to provide such receivers with minimum parts and maximum signal pick-up capabilities in relation to size.

The novel features which we believe to be characteristic of our invention are set forth in 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 we have indicated diagrammatically several circuit organizations whereby our invention may be carried into effect.

In the drawing:

Fig. 1 shows an embodiment of the invention, Fig. 2 graphically illustrates the operation thereof,

Fig. 2a shows a magnified portion of the curve of Fig. 2,

Fig. 3 illustrates a modification.

Referring, now, to the accompanying drawing, wherein like reference characters in the various figures designate similar circuit elements, Fig. 1 shows a highly simplified form of FM receiver. Essentially the receiver employs a super-regenerative detector tube 1, say of the screen grid type, provided with a tunable loop input circuit 2—3. The tube 1 has a cathode 4 connected by lead 5 to a point on loop 2. The tuning condenser 3 is adjustable to tune loop 2 over a desired ultra-high frequency range. When used for FM broadcast reception, the assigned band is 42 to 50 megacycles (mc.). In that band the channel width is 200 kilocycles (kc.) thereby permitting a carrier deviation of 150 kc. within each channel.

Those skilled in the art well know that at the transmitter, for FM broadcasting, the particular carrier frequency is deviated in accordance with the amplitude of the modulating audio frequencies, and the rate of deviation corresponds to the audio frequencies per se. At the receiver, therefore, for proper transmission of the received FM signal energy the input network to the demodulator should have a pass band of at least 150 kc. in width. According to our invention the loop 2, tuned by variable condenser 3, has a pass band which is capable of passing a channel exceeding 200 kc. in width. Preferably, and as shown in Fig. 2, the response curve of the tunable loop circuit has a linear portion which is some 200 kc., relative to the center frequency (F_c) of applied waves.

It is to be clearly understood that the present invention is not limited in any way to reception of high deviation FM waves, since the demodulator circuit shown herein is adapted to function with equal efficiency for narrow deviation FM waves. Furthermore, phase modulated carrier waves (PM) may be detected. In phase modulation the deviation is stressed at the higher modulation frequencies, and, therefore, a correction network for de-emphasizing the higher modulation frequencies would be utilized at a point following the demodulator. The term "angular velocity-modulated carrier waves" is generically employed herein to cover both FM and PM waves. The generic expression "timing modulated carrier waves" is alternatively utilized for the same purpose. In addition, it is to be clearly understood that where desired the present invention may be utilized for the reception of amplitude

modulated carrier waves, particularly where the carrier frequency is in the ultra-high frequency range. For example, the method of retaining the quench oscillation frequency during the first stage of audio amplification, which method is to be described in full at a later point, can be utilized with equal facility for the reception of amplitude modulated carrier waves.

Returning to the specific details of the circuit shown in Fig. 1, the tube 1 has its signal control grid 6 connected to the high potential side of tuning condenser 3 through the grid leak condenser 7. The grid leak resistor 8 is connected between the control grid 6 and ground. The plate 9 is connected to a point of proper positive potential on the energizing direct current source, not shown to preserve simplicity of disclosure, through a radio frequency choke coil 10 and an output load resistor 11.

The load resistor 11 is shunted by the carrier by-pass condenser 12. The modulation voltage developed across resistor 11 is adapted to be utilized by any desired audio amplifier network. The audio coupling condensers 13 may be utilized to transmit the audio voltage developed across resistor 11 to the audio utilization network. The screen grid of tube 1 may be connected to a point of proper positive potential through the resistor 14, the carrier by-pass condenser 15 connecting the screen grid lead to ground.

Where the energizing source utilizes a source of alternating current followed by a rectifier to supply the energizing direct current, the rectifier element may be included in the tube envelope of tube 1. For example, a tube of the 117N7GT type may be used for this purpose. In such case, the receiver would consist of a single tube, and the output of the detector could be supplied to any desired type of audio amplifier system. It is to be understood, of course, that the invention is not limited to energization from a rectified alternating current source. For example, a commercial direct current supply may be used. The invention may, also, be employed in connection with portable receivers of the type utilizing batteries for energizing the circuits.

In Fig. 2 there is graphically shown, in a purely qualitative manner, the response characteristic of the tunable loop input circuit of the detector 1. The coupling of cathode 4 to the loop 2 provides a regenerative feedback circuit which permits the signal energy to build up in the loop circuit to a point of self-oscillation. The constants of condenser 7 and resistor 8 are so chosen as periodically to quench, or interrupt, the oscillations in the tunable loop circuit so as to produce the well known super-regenerative effect. The quench frequency is preferably super-audible, and merely by way of illustration, may have a value of 20,000 cycles. It is to be clearly understood that this value of quench frequency is purely illustrative, it being only essential that the quench frequency be above the audio frequency range.

Merely by way of illustration, condenser 7 may have a magnitude of 150 micro-microfarads (mmf.) while resistor 8 may have a value of 200,000 ohms. The time constant of network 7-8 is chosen sufficiently long so as to permit the quenching of the oscillatory loop circuit at the desired frequency rate. Those skilled in the art are well aware of this phenomenon of super-regeneration, and know that the periodic interrupted oscillation will have a frequency determined by the frequency of loop circuit 2-3. In other words, the oscillatory frequency is deter-

mined by the setting of adjustable tuning condenser 3. As a result of the well known super-regenerative action the damping of the loop circuit is periodically greatly decreased. The loop circuit has a very sharp response characteristic.

Fig. 2 shows the manner in which such response characteristic would appear. While the response characteristic is sharp, yet it is readily capable of efficiently passing the desired FM channel. By virtue of this super-regenerative action the detector circuit is extremely sensitive, and provides efficient detection. That is, the modulation frequency voltage developed across resistor 11 will be relatively high. Indeed, the voltage will be of such magnitude that a single stage of audio amplification is sufficient to permit a reproducer to be driven. The insertion of the radio frequency choke coil 10 in the plate lead provides a second regenerative feedback path which is constituted by the inherent capacity 16, shown in dotted lines, existing between the plate 9 and the control grid 6.

The loop 2 may be as small as four inches square, although this dimension is not limiting, and, therefore, may be included in a small cabinet with the other circuit elements. It will now be seen that the loop 2 not only functions as the tunable inductance coil for the input circuit of the detector tube, but, also, provides a portion thereof to function as a feedback coupling coil for the cathode of detector tube 1. The tuning condenser 3 is adjusted to tune the loop to a small frequency value off the peak frequency of the response curve in order to secure efficient demodulation of the applied angular velocity-modulated carrier waves.

Assuming FM waves are being received, and that the center frequency of the desired FM channel is F_c , then condenser 3 is adjusted to tune the loop to one side of the peak frequency by a substantially small frequency spacing in order to secure detection such as will give modulation output of good quality and loudest volume. As shown in Fig. 2 there are four zones of possible demodulation. In the zone closest to peak frequency, and on either side thereof, the output of the detector is distorted and of weak volume. It can be stated, for example, that this zone extends for a few kilocycles on either side of the curve peak. In other words, if condenser 3 were adjusted to tune the loop to the peak frequency, then the output of the receiving system would be distorted and very weak.

Modulation output of good quality and loudest volume is secured in a second zone which covers a practically linear range of approximately 100 kc. on either side of the point denoted as F_c . Beyond that range there is a third zone in which demodulation produces good quality output of relatively strong intensity, but not as loud as in the aforementioned second zone. As noted in Fig. 2, adjustment of tuning condenser 3 to tune the loop to a relatively great frequency spacing from peak frequency on either side thereof, results in weak signals and a definite increase in noise level.

It will, therefore, be seen that for each incoming signal channel, condenser 3 is adjusted to point F_c of the response curve. In other words, the detector input circuit is tuned to one side of the center frequency of the response curve, and detection is produced by virtue of the linear portion $x-y$ of the response characteristic. It can be pointed out that this type of off-center frequency tuning to demodulate FM waves is known per se. In actual practice, the operator of the

receiver will find the optimum detection point on either side of the response curve center frequency F_c , but it will, also, be noted by the operator that the frequency spacing between these optimum detection points is relatively small considered from the viewpoint of the adjustment of the tuning device. The receiver operator actually will find it difficult to find the intermediate distortion point, and will find it much easier to adjust the loop to produce good quality output with loud volume.

In Fig. 2a there is shown in magnified form the linear portion $x-y$ of the response curve of Fig. 2. It will be seen that F_c is at the center of this linear portion. Further, the horizontal frequency spacing between x and y is 200 kc. Hence, demodulation can readily take place if the loop 2—3 is tuned to either point F_c of the response curve. Due to the linearity of the curve between points x and y the FM wave will be demodulated efficiently. Obviously the width of the curve in Fig. 2 between points $x-x$ will be in excess of 400 kc.

It may be desirable to utilize a stage of radio frequency amplification between the demodulator and the signal collector. For example, a pentode type tube may be used provided with a tunable input circuit which may have a damping resistor shunted thereacross to impart to it a wide response characteristics. The tuned input circuit could then be coupled to a signal collector of the grounded antenna type. It will, therefore, be seen that the present invention is not restricted to a loop circuit, but may be employed, where desired, with a grounded antenna circuit. It is preferred to have the tuned input circuit of such a prior ultra-high frequency amplifier sufficiently broad in response to pass all carriers in the 42 to 50 mc. band. Such a prior amplifier would act to prevent radiation of oscillatory energy from the super-regenerative circuit. The resistor 14 could be made adjustable to control regeneration.

In Fig. 3 there is shown a modification wherein a super-regenerative detector stage, two stages of audio amplification and the alternating current power supply rectifier may all be provided in a common compact receiver cabinet of the small type, using merely two tubes. The loop pick-up and the reproducer may, also, be provided within the compact cabinet. The loop 2 is shunted by the variable tuning condenser 3. Instead of relying on a section of the loop to provide regenerative feedback, a special coil 30 is provided in the grounded side of the loop. The cathode lead 5 is connected to the ungrounded end of coil 30. The tube 31 may be a pentode-triode employing independent cathodes; for example, a tube of the 25B8GT type may be utilized. The pentode section of tube 31 acts as the super-regenerative detector.

Condenser 7 and resistor 8 are connected as in Fig. 1; these elements again act to provide the periodic interruption of the oscillations built up across the loop circuit. The plate 32 is connected to its proper positive voltage point of the power supply source through the choke coil 10, carrier by-passed load resistor 11 and voltage reducing resistor 33. The screen grid, by-passed for carrier currents, may be connected to the upper end of resistor 33. It will be understood that the pentode section with its tunable loop circuit acts exactly as the screen grid detector in Fig. 1.

The triode of tube 31 acts as the first audio amplifier stage. The cathode 34 is grounded, while the grid 35 of the audio triode is coupled to the

resistor 37 of potentiometer 38—37 shunted across load resistor 11. Potentiometer 38—37 is connected from the plate end of resistor 11 to ground. Grid 35 is connected to ground by the grid leak resistor 39, while the slidable tap 40 of the potentiometer resistor 37 is connected to grid 35 by audio coupling condenser 41. Tap 40 may be used as the volume level control. The by-pass condenser 42 has a magnitude of approximately 250 mmf. The latter magnitude should not be sufficient to permit substantial filtering out of the quench frequency. In other words, and contrary to prior practice in super-regenerative circuits, the major filtering of the quench frequency is not accomplished until a point subsequent to the first audio amplifier.

We have found that a very substantial improvement in quality and volume occurs if the quench frequency currents are permitted to remain in the system through at least the first audio amplifier stage. The quench frequency may then be considered as a carrier of 20 kc. modulated by the audio. The first audio tube may be considered as functioning as a demodulator. The percentage modulation being low, the distortion introduced by this procedure is inconsequential. The improvement in amplification thus obtained over a system in which the quench is filtered out at the detector is very marked. This explanation is purely theoretical, and is given to explain an action which is entirely reversed from usual super-regenerative practice. We have found it to be highly advantageous in increasing receiver output volume to permit the quench frequency to pass through the first audio stage, and filter the quench thereafter.

The amplified audio output of the triode section 34—35—36 is developed across resistor 43. The latter may be inserted in circuit between plate 36 and resistor 33. The condenser 44 acts as a low frequency filter, while condenser 45 is connected from the upper end of resistor 43 to ground. Condenser 45 has a magnitude of 1000 mmf., and functions to filter off the quench frequency current at that point. We have found that the quench frequency is best removed prior to the second audio stage thereby preventing overload of the second audio stage. The second audio tube need not be used.

The second audio amplifier stage may comprise an audio power output tube 46 which may be of the beam type. For example, a tube of the 70L7GT type may be used. This type of tube contains a beam amplifier section as well as a diode section. The diode section functions as an alternating current rectifier, but the diode is omitted from Fig. 3 to preserve simplicity of disclosure. By including the diode as a part of the second audio tube, it will be seen that the receiver may consist of but two tubes. The second audio stage is of usual and well known form, and may comprise a properly by-passed self-bias resistor 47 connected between the cathode and ground.

The control grid of tube 46 is coupled to the upper end of resistor 43 by the audio coupling condenser 48, and grid leak resistor 49 connects the control grid to ground. The plate of tube 46 is connected to the primary winding of the output transformer 50, while the secondary winding may be connected to the voice coil of the reproducer. It will be understood, as stated before, that within the small receiver cabinet both the reproducer and loop 2 will be included. It will now be seen that there has been provided in the arrangement of Fig. 3 a highly efficient and com-

pact type of FM receiver wherein but two tubes are required to receive FM signals with quality and relatively loud volume, and wherein it is merely necessary to utilize a loop of small dimensions which can be located within the compact receiver cabinet. As explained in connection with Fig. 1, the loop 2 need only be of the order of 4 inches square to perform in a satisfactory manner. Of course, the receiving circuit shown in Fig. 3 may be energized from a commercial direct current supply source, or it may be energized by batteries as in the case of portable receivers of the so-called "personal" type.

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

What we claim is:

1. In a receiver of ultra-high frequency signal modulated carrier energy provided with a super-regenerative detector, the method which includes quenching the oscillations produced in the detector at a super-audible frequency, deriving signal modulation energy and quench frequency components from the detector, amplifying the signal modulation and quench frequency components, removing the amplified quench frequency component without in any way affecting the modulation component, and directly reproducing said signal modulation component.

2. A method of receiving signal modulated carrier waves of ultra-high frequencies which includes producing oscillations at a selected ultra-high frequency, quenching the oscillations at a super-audible rate thereby to provide super-regenerative amplification of the received carrier waves, demodulating the received carrier waves to provide modulation frequency components and a quench frequency component, subjecting both said modulation frequency and quench frequency components to amplification thereby greatly to increase the amplification of said modulation frequency components, removing substantially all the quench frequency component subsequent to said last amplification without in any way affecting the modulation component, and subjecting the amplified modulation frequency components to a repeated modulation frequency amplification.

3. In a receiver of angular velocity-modulated carrier waves, a super-regenerative detector provided with input and output electrodes, a tunable loop circuit coupled to said input electrodes, a modulation voltage utilization circuit coupled to said output electrodes, and said tunable loop circuit including means for adjusting the frequency of the loop to a frequency displaced from the response curve peak frequency by a frequency value sufficient to provide demodulation of applied carrier waves, said loop circuit having a response characteristic which is relatively sharp at its peak, and whose pass band adjacent the upper half of the characteristic is in excess of 200 kilocycles.

4. In a receiver of angular velocity-modulated carrier waves, a super-regenerative detector provided with input and output electrodes, a tunable loop circuit coupled to said input electrodes, means in circuit with the loop to provide quench oscillations, a modulation voltage amplifier circuit coupled to said output electrodes, and said tunable loop circuit including means for adjust-

ing the frequency of the loop, means for preventing removal of quench frequency components from the detector output circuit, and additional means operatively connected to the output of said amplifier circuit for filtering out quench frequency components.

5. In a frequency modulation receiver, a super-regenerative detector tube having input and output electrodes, a tunable loop circuit coupled to the input electrodes, an audio amplifier coupled to said output electrodes, solely a condenser-grid leak network connected to said input electrodes for providing quenching of oscillations produced due to regenerative action, said quenching being at a super-audible frequency, and said tunable loop circuit including an adjustable tuning element for tuning the loop circuit to different carriers in a relatively wide reception band.

6. In a frequency modulation receiver, a super-regenerative detector tube having input and output electrodes, a tunable loop circuit coupled to the input electrodes, an audio amplifier coupled to said output electrodes, solely a condenser-grid leak network connected to said input electrodes for providing quenching of oscillations produced due to regenerative action, said quenching being at a super-audible frequency, and said tunable loop circuit including an adjustable tuning element for tuning the loop circuit to different carriers in a relatively wide reception band, means for preventing filtering out of quench frequency components from any point between the detector tube output electrodes and the output circuit of said audio amplifier, and additional means for filtering said components from the output circuit of said audio amplifier.

7. In a receiver of signal modulated carrier signals provided with a super-regenerative detector, the method which includes quenching the oscillations produced in the detector at a desired frequency, deriving signal modulation energy and quench frequency components from the detector, amplifying the signal modulation and quench frequency components, but removing the amplified quench frequency component, and subsequently amplifying said signal modulation component.

8. A method of receiving modulated carrier waves of ultra-high frequencies which includes producing oscillations at a selected ultra-high frequency, quenching the oscillations at a desired rate thereby to provide super-regenerative amplification of received carrier waves, demodulating the received carrier waves to provide modulation frequency components and a quench frequency component, subjecting both said modulation frequency and quench frequency components to amplification thereby greatly to increase the amplification of said modulation frequency components, and removing substantially all the quench frequency component subsequent to said last amplification.

9. In a receiver of frequency modulated carrier waves, a super-regenerative detector provided with input and output electrodes, a tunable loop circuit coupled to said input electrodes, a modulation voltage utilization circuit coupled to said output electrodes, and said tunable loop circuit including means for adjusting the frequency of the loop, said loop circuit having a response characteristic which is relatively sharp at its peak, and whose pass band adjacent the upper half of the characteristic is of the order of 400 kilocycles.

10. In a receiver of frequency modulated carrier waves, a super-regenerative detector provided

with input and output electrodes, a tunable loop circuit coupled to said input electrodes, solely a condenser-resistor network connected to the loop circuit providing quench oscillations of a super-audible frequency, a modulation voltage amplifier circuit coupled to said output electrodes amplifying both modulation and quench oscillations, said tunable loop circuit including means for adjusting the frequency of the loop to a frequency displaced from the response curve peak frequency by a frequency value sufficient to provide efficient demodulation of applied carrier waves.

11. In a receiver of frequency modulated carrier waves, a super-regenerative detector provided with input and output electrodes, a tunable loop circuit coupled to said input electrodes, means in circuit with said loop circuit to provide super-audible quenching, a modulation voltage amplifier coupled to said output electrodes, said modulation amplifier having its electrodes in the same tube envelope as said detector, and said tunable loop circuit including means for adjusting the frequency of the loop to a fre-

quency displaced from the response curve peak frequency by a frequency value sufficient to provide demodulation of applied carrier waves, said loop circuit having a response characteristic which is relatively sharp at its peak, and whose pass band adjacent the upper half of the characteristic is in excess of 200 kilocycles.

12. In a receiver of frequency modulated carrier waves, a super-regenerative detector provided with input and output electrodes, a tunable loop circuit coupled to said input electrodes, a quench oscillation network in the loop circuit, a modulation voltage amplifier coupled to said output electrodes, the electrodes of the amplifier being in the same tube envelope as the detector electrodes, and said tunable loop circuit including means for adjusting the frequency of the loop, means for preventing removal of quench frequency components from the detector output circuit, and additional means operatively connected to the output of said amplifier for filtering out quench frequency components.

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