

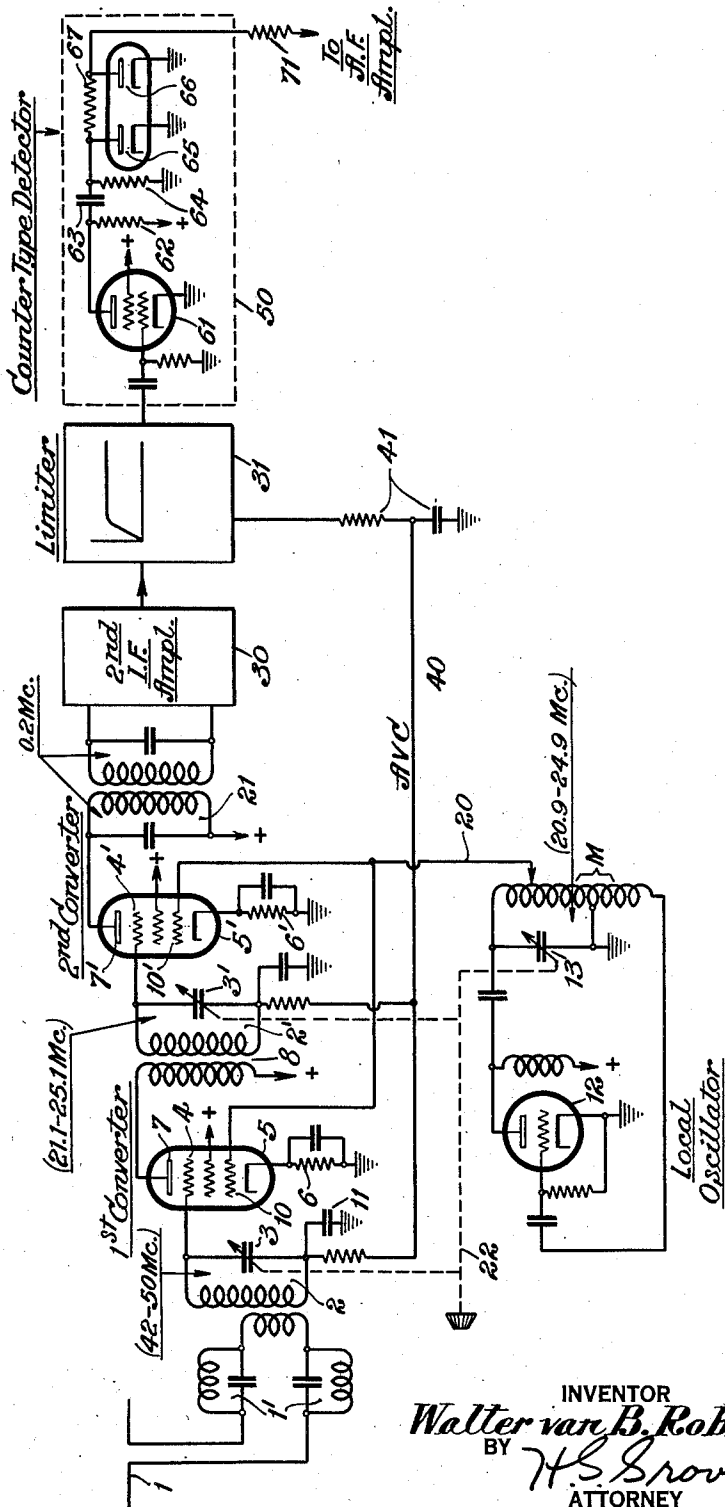
May 5, 1942.

W. VAN B. ROBERTS

2,282,092

FREQUENCY MODULATION RECEIVER

Filed March 26, 1941



INVENTOR
Walter van B. Roberts
BY *H. S. Grover*
ATTORNEY

UNITED STATES PATENT OFFICE

2,282,092

FREQUENCY MODULATION RECEIVER

Walter van B. Roberts, Princeton, N. J., assignor
to Radio Corporation of America, a corporation
of Delaware

Application March 26, 1941, Serial No. 385,246

8 Claims. (Cl. 250-20)

My present invention relates generally to a method of receiving frequency modulated carrier waves, and more particularly to a novel and improved receiver of the superheterodyne type adapted to receive frequency modulated carrier waves.

The usual receiver of frequency modulated waves employs a pair of rectifiers whose outputs are connected in opposition. Thus, when the frequency is at its mean, or carrier, value the outputs of the two rectifiers cancel so that amplitude variations of the carrier do not produce any direct current output. However, when the incoming waves are of different frequency from their mean value the cancellation is no longer complete, and amplitude variations reaching the rectifiers produce unwanted variations in the combined output circuit of the rectifiers. This susceptibility to disturbance from amplitude variations occurs whenever the wave frequency is varied; that is, most of the time. Hence, in present receivers an attempt is made to eliminate amplitude variations from the received waves before these are impressed on the rectifiers. Devices used for this purpose are generally known as limiters, and the function of a limiter is to limit the amplitude of a wave impressed thereon to a fixed value. Unfortunately, however, the mere limiting of amplitude is not sufficient to maintain the amplitude of the voltage impressed on the rectifiers independent of amplitude variations of the incoming signals. This is because tuned circuits are interposed between the limiter and the rectifiers, and the amplitude of the voltage developed in these tuned circuits depends not only upon the amplitude of the current pulse emanating from the limiter, but, also, upon the wave shape of this pulse and, hence, upon the amplitude of the incoming signal wave.

It can, therefore, be stated that it is one of the main objects of my present invention to provide an improved method of, and means for, converting frequency modulated carrier waves having undesired amplitude variations into a rectified current whose direct current component varies directly with the frequency of the collected modulated carrier waves but does not vary with amplitude variations of said waves.

In my application Serial No. 354,982, filed August 31, 1940, there are disclosed and claimed various arrangements for receiving frequency modulated carrier waves which seek to overcome the aforementioned drawbacks. Each of the arrangements operates on the principle of a counting circuit, and in effect counts the incoming

waves by producing from each wave a fixed quantum of electric charge regardless of the amplitude of the wave. The average flow of current produced by these quanta is, therefore, directly proportional to the frequency of the waves and independent of their amplitude. It will be evident that to produce a large percentage variation in the aforesaid average current, the mean frequency of the waves must be so low that the frequency variation due to modulation will be comparable to the mean frequency.

This condition is easily enough obtained in a superheterodyne type of receiver by making the mean, or carrier, value of the intermediate frequency only a little greater than the frequency deviation produced by modulation. Since the frequency deviation is usually less than a hundred kilocycles, the attainment of this condition requires using an intermediate frequency of the order of one or two hundred kilocycles (kc.) with the result that image interference is difficult to avoid. Thus, the "counter" type of FM (frequency modulation) detector is, also, subject to drawbacks when employed in connection with the usual type of superheterodyne receiver.

Another important object of my invention, therefore, is to utilize the aforesaid counter type of FM detector in a superheterodyne receiving system in which two frequency conversions take place, the same local oscillator being employed for each conversion; the cascade conversion resulting in the production of only one primary "image" frequency of the signal with respect to the first heterodyne, this single image frequency being the same as the second intermediate frequency.

Still other objects of the invention are to improve the reception of FM waves, and more especially to provide FM receivers which are reliable, efficient and economically manufactured and assembled.

The novel features which I believe to be characteristic of my 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 I have indicated diagrammatically a circuit organization whereby my invention may be carried into effect.

Referring, now, to the accompanying drawing, there is shown a superheterodyne receiving system adapted to receive FM waves, or in general "timing" modulated carrier waves. The pres-

ent FM reception band covers 42 to 50 megacycles (mc.). Let it be assumed that dipole signal collector 1 collects FM waves, and impresses the wave energy upon the tunable input circuit 2. The latter includes a variable tuning condenser 3 for adjusting the frequency of the circuit over the 42-50 mc. range. The FM waves, whose center frequency coincides with the frequency of circuit 2, are applied to the signal input electrode 4 of the first converter tube 5. The cathode of the latter may be connected to ground through a self-bias resistor 6 shunted by a carrier by-pass condenser. The plate electrode 7 is connected to the primary winding of transformer 8. An oscillation input electrode 10 is located between the positive screen of tube 5 and cathode. The low potential side of input circuit 2 is returned to ground for signal currents by the condenser 11.

Local oscillations are applied to electrode 10 by a local oscillator comprising a tube 12 having its control grid regeneratively coupled, as at M, to the tunable tank circuit provided with the adjustable tuning condenser 13. The tank circuit is in the plate to cathode circuit of tube 12, and the oscillator will be recognized as of a conventional construction. Adjustment of condenser 13 varies the frequency of the tank circuit over a range such as to produce a predetermined range of beat frequencies at the input circuit 2' of the second converter tube 5'. For example, the oscillator tank circuit may be adjusted over a frequency range of 20.9 to 24.9 mc. In that case, the variable tuning condenser 3' would be adjusted to tune the input circuit 2' over a range of 21.1 to 25.1 mc.

The second converter tube 5' may be constructed exactly like tube 5. Hence, corresponding elements bear the same reference numeral, except that in the circuit of tube 5' the numerals are given a "prime" designation. The local oscillations produced at the oscillator tank circuit are applied over lead 20 to the oscillation input electrodes 10 and 10'. The lower end of lead 20 terminates in an adjustable tap slidable along the coil of the oscillator tank circuit. The plate circuit of the second converter tube includes a resonant output circuit 21 tuned to a fixed frequency of 0.2 mc. The variable condensers 3, 3' and 13 will, of course, preferably be uni-controlled in any of the well known ways for producing satisfactory tracking of the circuits. The dotted line 22 denotes the usual mechanical adjustment device for varying the positions of the rotors of condensers 3, 3' and 13 in unison. The second I. F. value is a constant, and is much lower than the first variable I. F. value.

The second I. F. voltage is applied to the input circuit of the I. F. amplifier 30. The latter will provide predetermined amplification of the FM waves at the second I. F. of 0.2 mc. The amplified FM waves, at the second I. F. value, are applied subsequently to a limiter stage 31. The latter is schematically represented, since those skilled in the art well known how to construct such a network. Briefly, the limiter operates in the manner of a saturated amplifier, and has an input-output characteristic as shown in the rectangle 31. The limiter functions to minimize amplitude variations in the FM carrier. Usually its grid circuit includes a resistor, shunted by an I. F. by-pass condenser, across which is developed a uni-directional voltage proportional to carrier amplitude. The voltage may be applied over lead 40, including appropriate

pulsation filter 41, variably to bias the signal grids of converters 5 and 5'. This is very well known, and, of course, any other well known AVC circuit may be used to control the bias of each of the converter signal grids. In place of the AVC circuit, each converter grid circuit can include a grid condenser and leak to limit the plate output from extremely strong signals. Further, the converters may be of any desired type; the only requirement is that cascade conversion with a common oscillator circuit be employed.

The dotted rectangle 50 denotes the counter-type of FM detector disclosed as Fig. 6 of my aforesaid application. While the invention is by no means restricted to such detector, it is shown to illustrate the present system. The limiter 31 feeds the limited FM signals to the input electrodes of screen grid amplifier tube 61. The plate circuit of tube 61 includes a resistor 62. The plate end of resistor 62 is coupled by condenser 63 to the upper end of resistor 64. The diode 65 is connected between the upper end of resistor 64 and its grounded end. A second diode 66 has its anode connected to the anode of diode 65 through resistor 67, while the anode of diode 66 is further connected to the input grid of the following audio amplifier tube (not shown) through resistor 71. The cathode of diode 66 is at ground potential. The plate circuit of the following audio amplifier tube, properly by-passed, may feed the detected audio voltage to any desired type of reproducer.

The plate resistor 62 develops a square wave of voltage, while condenser 63 has passed through it a definite quantum of charge at each half cycle of the square wave voltage. The resistor 64 develops a voltage from the passage of the aforesaid charge in one direction, and the following audio amplifier tube is energized by this voltage. The pair of diodes 65-66 are arranged in combination with resistors 67-71 to form a "polarity filter" to permit the transfer of negative potential pulses from resistor 64 to the audio amplifier, but to suppress positive potential pulses. The constants are so chosen as to permit the system to assume steady state conditions within the time during which the flat-topped plate potential wave stays constant at a limiting value.

If E is the maximum potential change across resistor 62, and F the frequency of the limited wave, then the charge displacement per cycle is CE (where C is the capacity of condenser 63), and the average current through resistor 64 is FCE. The average voltage impressed on the final amplifier grid is FCER, where R is the resistance of element 64. If desired, the anode of diode 65 and cathode of diode 66 may be strapped together, and resistors 67 and 64 omitted. In such case the cathode of diode 65 would be grounded, and the anode of diode 66 would be connected to ground through an output resistor feeding the audio circuit through an audio filter network. In such case, as before, an increase in the repetition rate of the FM waves applied at the input of tube 61 will increase the number of current pulses per unit of time, and, therefore, increase the average value of current flowing through the output resistor. Conversely, a decrease in repetition rate decreases the average current through the output resistor, and the average potential across the latter is a perfectly linear function of the frequency of the input signal.

Returning, now, to the question of image fre-

quency, it will be seen that when the frequency of the local oscillator is 20.9 mc., the only frequency, other than the desired 42 mc. carrier, which is capable of producing, by beating with the oscillator, the first intermediate frequency value of 21.1 mc., is the frequency 0.2 mc. which by addition to the oscillation frequency will produce the first intermediate frequency value. Similarly, when the oscillator is adjusted to 24.9 mc. and the signal is 50 mc., the first intermediate frequency value being 25.1 mc., the only image frequency is again 0.2 mc. It can, in fact, be demonstrated that for any signal in the tuning range, the only image interference that can be caused is that which occurs at the single frequency of 0.2 mc. However, this latter frequency is so low, when the second intermediate frequency value is chosen as in the present illustration, that the short wave dipole antenna 1 is very little responsive to the image frequency, and the antenna tuned input circuit 2 is far off-tune from the image frequency in addition. Furthermore, and as shown in the drawing, it is a simple matter to insert one or more wave traps 1' at the antenna circuit which will further greatly attenuate interference at the particular image frequency without appreciably affecting the signal frequency response, since the difference is so great between the frequencies involved.

While the value of 0.2 mc. has been given as illustrative, of course other values may be used in accordance with the invention. What is essential in the present invention is that the second intermediate frequency value be so low that the frequency variations due to modulation be comparable to the intermediate frequency value, but not so low that the spectrum of the modulated wave contains any considerable frequency components as low as the upper limit of audibility. Of course, the lower the second intermediate frequency value can be made, without introducing undesirable effects of any sort or without increasing circuit design difficulties or expense, the better, as the result is increased audio output for a given frequency modulation.

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 a receiver of timing modulated carrier waves, a first converter network having a signal input circuit and a signal output circuit, means for tuning said input circuit over a range of desired carrier frequencies, a local oscillator including means for varying the frequency thereof over a range of frequencies substantially different from the frequency range of said input circuit, the said output circuit including means for tuning it over a range of frequencies which represents the difference between said input frequency range and said oscillator frequency range, means for applying oscillations from said oscillator to said converter, a second converter provided with input electrodes coupled to said first converter output circuit, said second converter having an output circuit, means for applying oscillations from said oscillator to said second converter, said second converter output circuit being fixedly tuned to a constant frequency which is equal to the difference between the frequencies of said

oscillator and the output of said first converter, means for producing from said modulated waves a fixed quantum of charge, means for integrating said charges to produce a flow of current proportional to the frequency of said waves and independent of their amplitude, the frequency of said oscillator, at any point in its range, being such that twice its frequency is less than the frequency of a desired carrier wave by an amount which is greater than, but greater only by an order of magnitude or less, than the maximum frequency deviation of the desired waves from their center frequency.

2. In a superheterodyne receiver of the frequency modulation reception type, at least two converter stages arranged in cascade, each of said stages being provided with an input circuit and an output circuit, a local oscillator provided with a resonant tank circuit, means for tuning the first converter input circuit over a range of desired modulated carrier waves, means for adjusting the frequency of said tank circuit over a range of oscillation frequencies which are substantially different from the desired carrier frequency range, means for applying oscillations from said oscillator to both said converters, means for tuning the input circuit of the second converter through a range of frequencies equal to the difference between the carrier frequency range and the oscillator frequency range, said oscillator frequency range being chosen to have said second converter input circuit frequency range different from the oscillator frequency range by a relatively small constant frequency difference, said second converter output circuit being tuned to said small frequency difference, means for producing from said modulated waves a fixed quantum of charge, means for integrating said charges to produce a flow of current proportional to the frequency of said waves and independent of their amplitude, and means for simultaneously adjusting the tuning of said first converter input circuit, said second converter input circuit and said oscillator.

3. A receiver of frequency modulated carrier waves comprising a source of signal waves, a local oscillator, a first converter stage having connections to said signal source and oscillator, said converter having an output circuit tuned to the difference of frequency between signals from said source and oscillations from said oscillator, a second converter stage having a signal input coupling circuit to said first converter output circuit and also provided with an output circuit, means for applying oscillations from said oscillator to said second converter, said second converter output circuit being tuned to the difference frequency of voltages produced in said first converter output circuit and the frequency of oscillations from said oscillator, means for generating from carrier waves produced in said second converter output circuit a fixed quantum of charge, means for integrating said charges to provide a flow of current proportional to the frequency of said waves and independent of their amplitude, and the frequency of said oscillator being so chosen that twice its frequency is less than the frequency of the desired signal waves by an amount which is greater than, but greater only by an order of magnitude or less than, the maximum frequency deviation of the signal waves from their mean frequency.

4. The method of receiving and demodulating frequency modulated waves which comprises generating local oscillations whose frequency is

half the difference between the mean frequency of said waves and a constant frequency which constant frequency is greater than, but only a few times greater than, the maximum frequency deviation of said waves, combining said oscillations with said waves to produce waves of a first intermediate frequency, combining said same oscillations with said first intermediate frequency waves to produce waves of a second intermediate frequency whose mean frequency is said constant frequency, utilizing said second intermediate frequency waves to produce fixed and equal quanta of charge displacement from each of said waves, accumulating the charge displacements in one direction to provide a current having a direct component proportional to the frequency of the waves of said second intermediate frequency but independent of the amplitude thereof, and utilizing the variations of said direct component to reproduce signals represented by the frequency modulation of said first named waves.

5. In a receiver of frequency modulated carrier waves, a first converter network having a signal input circuit and a signal output circuit, means for tuning said input circuit over a range of desired carrier frequencies, a local oscillator including means for varying the frequency thereof over a range of frequencies substantially different from the frequency range of said input circuit, the said output circuit including means for tuning it over a range of frequencies which represents the difference between said input frequency range and said oscillator frequency range, means for applying oscillations from said oscillator to said converter, a second converter provided with input electrodes coupled to said first converter output circuit, said second converter having an output circuit, means for applying oscillations from said oscillator to said second converter, said second converter output circuit being fixedly tuned to a constant frequency which is equal to the difference between the frequencies of said oscillator and the output of said first converter, means for demodulating said modulated waves, the frequency of said oscillator, at any point in its range, being such that twice its frequency is less than the frequency of a desired carrier wave by an amount which is greater than, but greater only by an order of magnitude or less, than the maximum frequency deviation of the desired waves from their center frequency.

6. In a superheterodyne receiver of the frequency modulation reception type, at least two converter stages arranged in cascade, each of said stages being provided with an input circuit and an output circuit, a local oscillator provided with a resonant tank circuit, means for tuning the first converter input circuit over a range of desired modulated carrier waves, means for adjusting the frequency of said tank circuit over a range of oscillation frequencies which are sub-

stantially different from the desired carrier frequency range, means for applying oscillations from said oscillator to both said converters, means for tuning the input circuit of the second converter through a range of frequencies equal to the difference between the carrier frequency range and the oscillator frequency range, said oscillator frequency range being chosen to have said second converter input circuit frequency range different from the oscillator frequency range by a relatively small constant frequency difference, said second converter output circuit being tuned to said small frequency difference, means for demodulating said modulated waves, and means for simultaneously adjusting the tuning of said first converter input circuit, said second converter input circuit and said oscillator.

7. A receiver of frequency modulated carrier waves comprising a source of signal waves, a local oscillator, a first converter stage having connections to said signal source and oscillator, said converter having an output circuit tuned to the difference of frequency between signals from said source and oscillations from said oscillator, a second converter stage having a signal input coupling circuit to said first converter output circuit and also provided with an output circuit, means for applying oscillations from said oscillator to said second converter, said second converter output circuit being tuned to the difference frequency of voltages produced in said first converter output circuit and the frequency of oscillations from said oscillator, means for deriving from carrier waves produced in said second converter output circuit modulation signals, and the frequency of said oscillator being so chosen that twice its frequency is less than the frequency of the desired signal waves by an amount which is greater than, but greater only by an order of magnitude or less than, the maximum frequency deviation of the signal waves from their mean frequency.

8. The method of receiving and demodulating timing modulated waves which comprises generating local oscillations whose frequency is half the difference between the mean frequency of said waves and a constant frequency which constant frequency is greater than, but only a few times greater than, the maximum frequency deviation of said waves, combining said oscillations with said waves to produce waves of a first intermediate frequency, combining said same oscillations with said first intermediate frequency waves to produce waves of a second intermediate frequency whose mean frequency is said constant frequency, and utilizing said second intermediate frequency waves to produce signals represented by the frequency modulation of said first named waves.

WALTER VAN B. ROBERTS.