July 3, 1945. W. R. KOCH 2,379,721

FREQUENCY MODULATION RECEIVING SYSTEM

Filed June 4, 1943 2 Sheets-Sheet 1

Fig. 1.

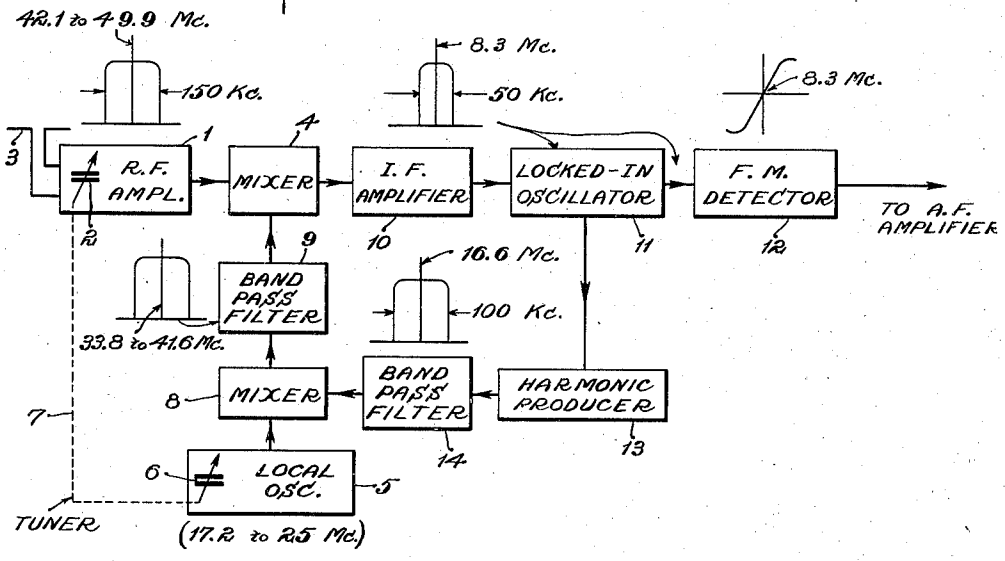
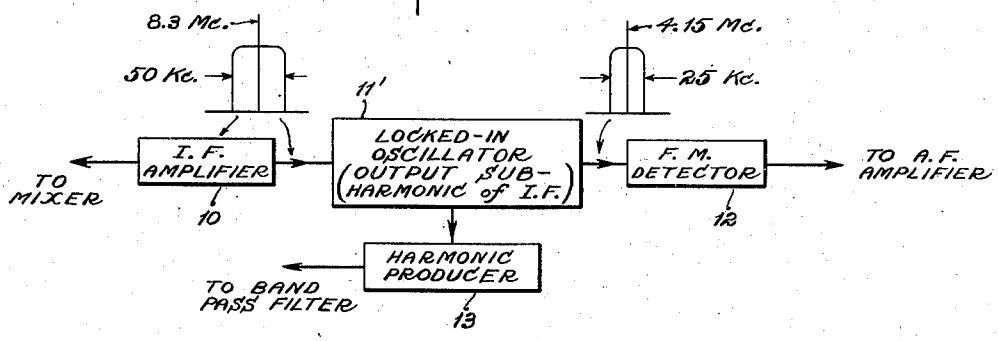


Fig. 2.



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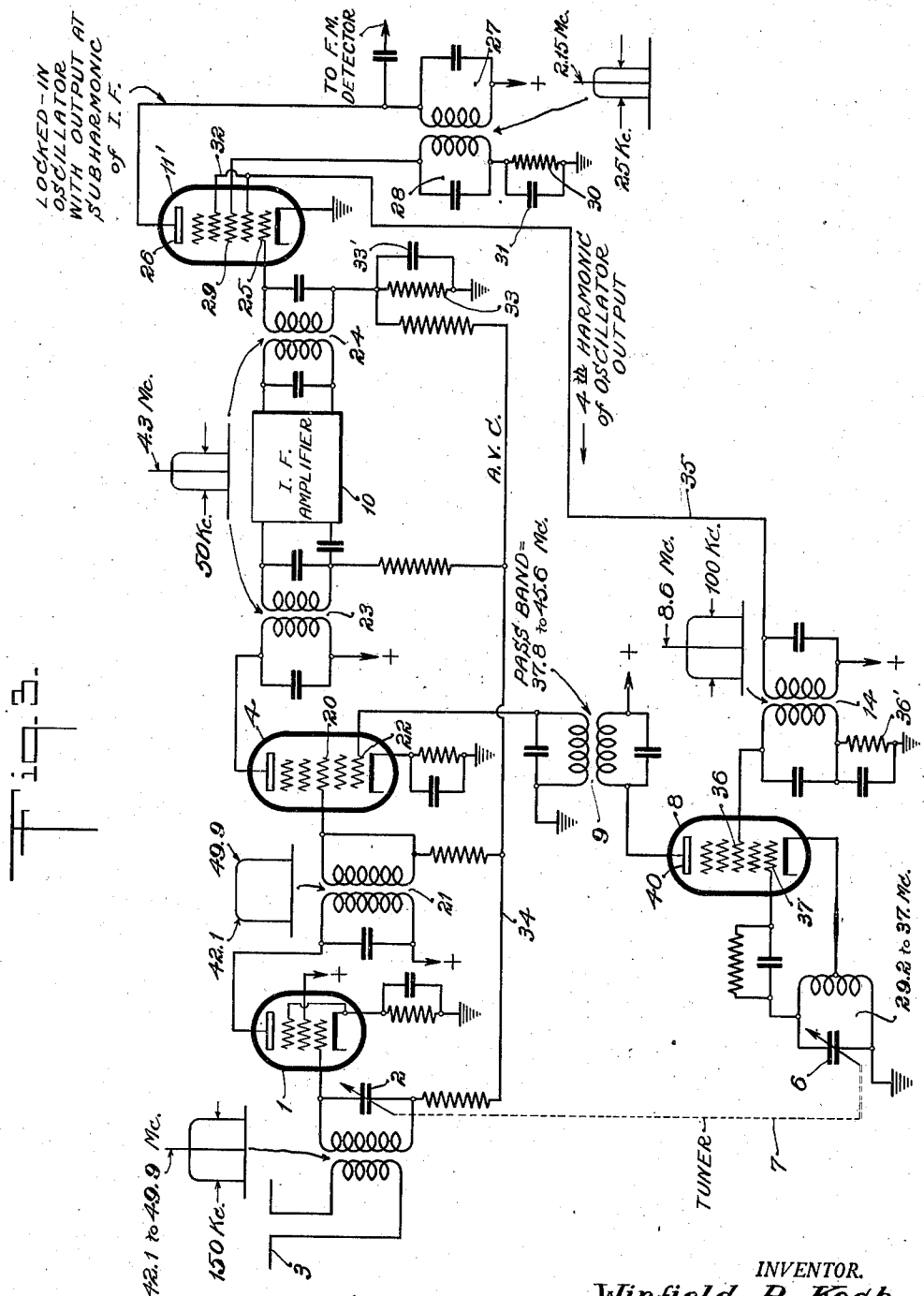


Fig. 2.

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FREQUENCY MODULATION RECEIVING SYSTEM

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Application June 4, 1943, Serial No. 489,622

14 Claims. (Cl. 250—20)

My present invention relates generally to systems for receiving angle modulated carrier wave energy, and more specifically to receiving systems for frequency modulated carrier waves.

In communication by angle modulation of high frequency carrier waves, it is necessary at the receiver to provide wave transmission networks capable of efficiently transmitting the entire band of modulated wave energy. By the expression "angle modulation" there is generically comprehended frequency modulation ("FM" hereinafter for brevity), phase modulation or hybrids of the two. By way of specific illustration the remainder of this specification is directed to frequency modulated carrier waves. In the reception of the latter with a superheterodyne receiver, a mode of reception which is practically universal, it is necessary to design the various selector circuits up to the demodulator so that the entire range of frequency deviation of a selected station passes efficiently. For example, in the FM broadcast band of 42 to 50 megacycles (mc.) there is employed a frequency deviation up to 75 kilocycles on either side of the midband, or center, frequency of the transmitter. Hence, the selector circuits at the receiver have been designed to pass a band 150 kc. wide.

In the intermediate frequency (I. F.) amplifier circuits such a relatively wide pass band reduces the gain per stage. Hence, there must be supplied sufficient stages of I. F. amplification to compensate for the loss of gain due to the wide pass band. Accordingly, it is one of the main objects of my invention to provide a novel and highly improved method of reducing the range of frequency deviation, or swing, of the FM wave energy at the converter network so that the I. F. selector circuits feeding the F. M. detector may have a relatively narrowed band width whereby greater gain per stage can be secured in the I. F. amplifier.

In the past various methods have been proposed to provide reduction of the range of frequency deviation of FM waves at the receiver. Some systems have accomplished the reduction by employing a reactance tube as a frequency modulation device at the receiver local oscillator, the local oscillations being frequency modulated by audio frequency so phased that the oscillations deviate in the same direction as the incoming signal, but with less deviation. Such systems are complex, and require careful adjustment of phase relations throughout the system. Again, in certain systems there has been employed prior to the demodulator a locked-in oscillator operating at a sub-harmonic of the I. F. wave energy. While such systems are generally satisfactory, the oscillator must lock in with the signal over a wide range of frequencies. This makes the oscillator design and adjustment relatively more difficult.

Hence, it can be stated to be another important object of this invention to provide a method of narrowing the frequency deviation range of the I. F. wave energy thereby to secure the benefits of narrow pass band characteristics in the I. F. selector circuits; the method basically including deriving an harmonic, preferably the second, from the I. F. wave energy in the presence of such energy, mixing the harmonic wave energy with the local oscillations, and then using the sum of the mixed energies as the heterodyne energy for received FM wave energy.

Another important object of my invention is to provide a method of superheterodyne reception of FM waves wherein there is employed in the I. F. amplifier network a locked-in oscillator from which the harmonic of the I. F. wave energy is obtained; the I. F. network feeding the oscillator having a relatively restricted pass band width compared to the frequency swing of the received FM waves whereby the locked-in oscillator does not have to lock in over as wide a percent deviation as would be the case if the applied signal had a frequency deviation range as wide as that of the received waves.

A more specific object of my present invention is the provision of an FM receiver of the superheterodyne type wherein a locked-in oscillator is employed in the I. F. amplifier network, narrowing of the frequency deviation range of the FM wave energy being secured at the input terminals of the I. F. amplifiers; or in a modification some narrowing can be secured at the input terminals of the I. F. amplifier and some at the oscillator output terminals whereby the over-all stability of the I. F. amplifier is improved.

Still other objects of my invention are to improve generally the efficiency and operation of FM receivers, and more especially to provide a superheterodyne receiver of FM wave energy of relatively high deviation ratio wherein the I. F. selector circuits are of a narrow pass band, and the receiver being economically manufactured and assembled.

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 drawings, in which I have in-

dicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawings:

Fig. 1 schematically shows one embodiment of the invention,

Fig. 2 schematically shows a modification,

Fig. 3 is a circuit diagram of a receiving system based on the modification of Fig. 2.

Referring now to the accompanying drawings, wherein like reference characters in the different figures denote similar circuit elements, let it be assumed that the receiver in Fig. 1 is of the superheterodyne type employed in the presently assigned FM range of 42–50 mc. Further, let it be assumed that the operating I. F. value is of the order of 8.3 mc. Actually, I prefer an I. F. value of 8.33 mc., since this value seems to give the least trouble from spurious responses in the present FM band. It will be understood, of course, that the invention is not limited to any specific frequency values. The sytem may be used to receive FM waves in any of the ultra-high frequency ranges; the I. F. value may be in the kilocycle or megacycle ranges; and the degree of frequency reduction may be greater than that disclosed herein.

The radio frequency amplifier **1** may embody one or more tunable selector circuits. The symbol **2** represents the tuning mechanism of the amplifier. The FM wave energy collector **3** is shown as a dipole feeding the tunable amplifier. The received modulated carrier wave energy will have a wave form wherein the mean frequency is deviated in accordance with the amplitude of the modulation signals applied to the carrier at the transmitter. The rate of frequency deviation is a function of the modulation frequencies per se. It is assumed that the maximum frequency deviation on either side of the mean frequency of the transmitted wave energy is approximately 75 kc. Hence, the over-all maximum frequency swing of the received FM wave energy is 150 kc.

In such case the tunable selector circuits of the radio frequency amplifier **1** will each have a pass band width of at least 150 kc. Above the amplifier **1** there is shown a curve which represents the pass band width of each of the selector circuits of the amplifier network. The midband frequency is represented as being capable of variation from 42.1 to 49.9 megacycles. In other words, the representation above the rectangle **1** conveys the information that each selector circuit is capable of being tuned through a frequency range of 42.1 to 41.9 mc., and at each selected mean frequency the selector band width will be 150 kc.

The selected FM wave energy is transmitted to a mixer network **4**. Concurrently with the selected and amplified FM wave energy there is fed to the mixer **4** heterodyne oscillations. The numeral **5** designates the usual local oscillator of a superheterodyne receiver. The symbol **6** denotes the usual tuning means of the oscillator. The tuning means **6** will be capable of adjusting the local oscillations through a frequency range of 17.2 to 25 mc. The dotted line **7** designates any well known form of unicontrol mechanism for concurrently adjusting the tuning mechanisms **2** and **6**, so as to secure the required "tracking." The locked-in oscillator **11** is designed to operate at the mean I. F. value, e. g., 8.3 mc., and produces oscillations whether or not I. F. wave energy is supplied to it. It is constructed in a known manner so as to follow I. F. changes over a range of frequencies on either side of 8.3 mc. The local oscillations produced by oscillator **5** are transmitted to a mixer network **8** where the local oscillations are mixed with the second harmonic energy derived from the locked-in oscillator. The resultant mixed energy will be of a frequency within a range of 33.8 to 41.6 mc., depending upon the adjustment of the local oscillator tuning mechanism **6**. The output energy from mixer **8** is passed through a band pass filter **9** which should be designed to efficiently transfer any frequencies in the band between 33.8 and 41.6 mc. The filter **9** should be capable of passing 33.8 mc. minus 50 kc., and should also be capable of passing 41.6 mc. plus 50 kc. The curve adjacent the filter **9** represents this design of the band pass filter.

The output energy of filter **9** is fed to the mixer **4** as the actual heterodyning energy. At any setting of the tuning mechanisms **2** and **6**, the modulated wave energy output of mixer **4** will have a mean frequency value of 8.3 mc. The I. F. amplifier **10** may comprise one or more stages of intermediate frequency amplification and the resonant selector circuits thereof will each be tuned to a frequency of 8.3 mc. In addition, each selector circuit will have a pass band width of only 50 kc. In other words, at the output terminals of mixer **4** there has been provided a reduction of the frequency deviation range of the received FM wave energy. There has, also, been provided a frequency reduction of the mean frequency of the received FM carrier waves.

Accordingly, the selector circuits subsequent to the mixer may be narrowed to one-third the pass band width of the selector circuits ahead of the mixer. This pass band narrowing is due to the fact that the heterodyne energy fed to mixer **4** has an effective frequency deviation of 100 kc., while the original FM wave energy fed to mixer **4** has a frequency deviation range of 150 kc. The process of mixing these energies results in a production of intermediate frequency energy, whose frequency deviation is the difference between the frequency deviation range of the original signals and that of the heterodyne energy. The frequency swing at the output of mixer **4** will be reduced, because, for example, at the instant the signal has deviated 75 kc. in the higher frequency direction, the heterodyne frequency will have deviated 50 kc. in the same direction. This will make the beat note equal to the I. F. plus 25 kc. The maximum deviation of the I. F. is 25 kc.

The numeral **11** denotes the previously mentioned locked-in oscillator of any well known construction. Those skilled in the art of FM reception are well acquainted with such an oscillator. Such an oscillator tends to oscillate at about the midband frequency of 8.3 mc., but is capable of following the frequency deviations of the energy at its input terminals over a restricted range of frequency. Thus, the oscillator **11** will lock in with the I. F. energy fed to its input terminals, and it will follow the frequency deviations. In other words, the output of oscillator **11** will be a replica of the I. F. energy fed to its input terminals. However, by providing a relatively narrow frequency deviation range of 50 kc. at the input terminals of oscillator **11**, the latter does not have to lock in over as wide a percent of deviation as would be the case if the signal energy fed to the oscillator were at the original wide deviation range of 150 kc. Moreover, a greater gain per stage of I. F. amplification is

secured by employing the relatively narrow pass band in each amplifier stage. In addition, the alignment of the selector circuits in the I. F. amplifier 10 is easier than in the case of the relatively wider pass band circuits.

The output of the locked-in oscillator, whose oscillations have a mean frequency equal to 8.3 mc. but whose frequency deviations are a replica of the frequency deviations of the I. F. energy fed to the oscillator, is then applied to an FM detector network 12. The latter may be of any well known type. Its typical S-shaped characteristic, with a center frequency of 8.3 mc., is represented above the rectangle 12. By way of specific example, there may be employed for the detector 12 the type of circuit shown by S. W. Seeley in his U. S. Patent No. 2,121,103, granted June 21, 1938. It is indicated by arrow indications that the response characteristic shown above rectangle 10 is employed for the various selector circuits ahead of the locked-in oscillator 11 and for the input circuit of the detector 12.

A portion of the oscillatory output of locked-in oscillator 11 is transmitted to a harmonic producer 13. Any well known form of device for producing harmonics of oscillations may be employed. In general, there may be used any non-linear device capable of providing rich harmonics. Specifically, there is used the second harmonic of the energy delivered by oscillator 11. This means that the output of the harmonic network 13 will have a mean frequency of 16.6 mc. The frequency deviation range will be multiplied by two so as to provide an over-all frequency swing up to 100 kc. Hence, the band pass filter 14 is designed to pass energy having a center frequency of 16.6 mc., and a maximum frequency deviation range of 100 kc. The output of filter 14 is applied to the mixer 8. Accordingly, it will be seen that the output of the mixer necessarily will cover a range of 33.8 to 41.6 mc., depending upon the adjustment of the oscillator tuning device 6.

In general, then, Fig. 1 shows a method of reducing the frequency deviation range of received FM signal energy by operating a locked-in oscillator at the operating I. F. value, and the second harmonic of the locked-in oscillations being employed to mix with the locally-produced oscillations to provide a range of sum heterodyne oscillations. At each selected sum frequency, the frequency deviation range is two-thirds that of the original frequency deviation range. Further mixing with the original FM wave energy provides beat frequency energy whose effective frequency deviation range is one-third the original frequency deviation range.

The locked-in oscillator is not necessary for operation of the receiver, as part of the I. F. energy may be applied to the discriminator and part to the harmonic producer directly. However, in such a circuit the presence of a signal in the I. F. network requires the presence of a signal in the harmonic producer. That is, the receiver will work once it has been started working. Although the signal may build itself up, it is usually necessary to apply oscillations to the harmonic producer to start the receiver. By using the locked-in oscillator, heterodyne energy is always present, and no build-up time or starting oscillations are required.

Further deviation reduction may be secured at the output terminals of the locked-in oscillator. In Fig. 2 the I. F. amplifier 10 is shown coupled to an oscillator network 11' whose output circuit feeds energy at a sub-harmonic of the I. F. to the FM detector 12. For example, the mean frequency of the FM wave energy at the oscillator output circuit may be one-half of 8.3 mc., or 4.15 mc. The overall frequency deviation will, therefore, be reduced to 25 kc. This means that the coupling network between oscillator 11' and the detector 12 need have a pass band only 25 kc. wide. However, where reproduction of modulation frequencies up to 15,000 cycles is desired, the coupling network must, of course, have a pass band 30 kc. wide. The fourth harmonic of the oscillator energy, however, is fed to filter 14 by passing a portion of the fundamental oscillations to the harmonic producer 13, as in the case of Fig. 1. Accordingly, there has been secured a frequency deviation range reduction to one-sixth in the system of Fig. 2. This has the advantage of reducing the noise ahead of the locked-in oscillator, because of the narrowed band and the frequency reduction between the I. F. amplifier and discriminator. The over-all stability of the I. F. amplifier is improved, because the oscillator output, which is relatively large, is at a different frequency from the I. F. amplifier which responds to relatively small signal voltages.

There may be employed for the locked-in oscillator 11' a system of the type disclosed and claimed in application Serial No. 430,588 of G. L. Beers, filed February 12, 1942, granted August 22, 1944, as U. S. Patent No. 2,356,201. In that locked-in oscillator, the energy fed to the discriminator section of the following demodulator is a submultiple harmonic of the I. F. energy controlling the oscillator. This present system tends to provide automatic frequency control (AFC) action. It is no harder to tune the receiver, or to keep the latter tuned, than other forms of receivers. The tendency of the receiver to "hang on" to a signal when the tuning control is operated can be readily controlled by the band pass filters employed and by adjustment of the lock-in range of the locked-in oscillator.

In Fig. 3 I have shown a complete receiving system embodying the general method of Fig. 2. There is secured a 3:1 narrowing prior to the locked-in oscillator, and an additional 2:1 narrowing in the locked-in oscillator. The specific form of the locked-in oscillator is that of the aforesaid Beers application, save that I derive fourth harmonic of the oscillator energy from the screen circuit of the locked-in oscillator tube. The amplifier 1 has its tuning device 2 tune the resonant input circuit over a range of mean frequencies from 4.1 to 49.9 mc. The over-all frequency swing is 150 kc. The mixer tube 4, of the well known pentagrid tube form, has its input grid 20 coupled to the plate circuit of amplifier 1 by a wind-band transformer 21.

Thus, the tuned primary and secondary circuits of transformer 21 are designed to pass a band from 42.1 mc. (less 75 kc.) to 49.9 mc. (plus 75 kc.) The grid 22 of the mixer tube 4 has applied to it the sum frequency energy fed from band pass filter 9. The sum frequency energy, as shown in Fig. 1, has a band of 100 kc., and covers a range of 37.8 to 45.6 mc. Since the operating I. F. used in this system is to be 4.3 mc., the local oscillator tuning means will cover a range of 29.2 to 37 mc. The I. F. amplifier 10 has its input transformer 23 designed to pass a band 50 kc. wide at a mean frequency of 4.3 mc. The output transformer 24 is similarly designed to pass the same band of FM energy to the input grid 25 of locked-in oscillator tube 11'. As stated previously this oscillator circuit is constructed

in accordance with the teaching of G. L. Beers in his aforesaid application.

The plate 26 is connected to a source of positive potential through a resonant circuit 27 which is tuned to one-half the I. F. value. In other words, the circuit 27 is tuned to 2.15 mc. The resonant circuit 27 is magnetically coupled to resonant circuit 28. Circuits 27 and 28 are coupled to cause the tube to oscillate at the resonant frequency of circuit 27. The high potential side of circuit 28 is connected to the intermediate grid 29 of the pentagrid tube 11'. The low potential side of circuit 28 is connected to ground through a resistor 30 which is bypassed for high frequencies by a condenser 31. The positive shielding grids 32 are located on either side of grid 29. As disclosed in the aforesaid Beers application, the plate 26 is coupled to grid 29 to provide oscillations at a sub-multiple harmonic of the input I. F. energy. In other words, oscillator 11' functions in the manner of a locked-in oscillator which has an output reduced in frequency by one-half.

Automatic volume control bias for the control grids of the prior tubes is provided by direct current voltage developed across grid resistor 33. The latter is arranged between the low potential side of the input circuit for grid 25 and ground. The resistor 33 is bypassed by condenser 33' for high frequency currents. Lead 34 connects the grid end of resistor 33 to the various signal grid circuits of tubes 1, 4 and amplifier 10 through proper filter resistors. The lead 34 is designated "AVC" to show that it is the usual automatic volume control circuit.

The fourth harmonic energy to be fed to the mixer tube 8 is derived in a novel manner from the screen circuit of the oscillator tube 11'. The harmonic energy is produced in the screen circuit, since its characteristic is non-linear. Thus, lead 35 is shown connected from the screen grids 32 to the high potential side of the resonant primary circuit of band pass filter transformer 14. This transformer has its primary and secondary resonant circuits tuned and designed so as to pass a band of frequencies 100 kc. wide at a mean frequency of 8.6 mc. The harmonic energy is applied to the grid 36 of mixer tube 8. The grid 37 of the mixer tube is coupled to the high potential side of tunable tank circuit controlled by tuning means 6, while the cathode of the mixer tube is connected to a tap on the tank circuit. It will be recognized that there is thus provided a source of local oscillations which is capable of being tuned through a frequency range of 29.2 to 37 mc.

Hence, at the various settings of the tuning means 6 there will be developed in the plate circuit of mixer tube 8 the sum frequency energy of the local oscillation energy and the harmonic energy fed to grid 36. The grid 36 is grounded through resistor 36' which is bypassed. The plate 40 of mixer tube 8 is connected to a suitable source of positive potential through the primary resonant circuit of the band pass filter 9, reference being made to Fig. 1. The transformer 9 has its primary and secondary circuits tuned and designed so as to have a pass band covering a range of 37.8 to 45.6 mc., as previously explained. The cut-off frequency will be decreased by 50 kc. at its lower range, and increased by 50 kc. at the upper end of the band. In this way, there is fed to the grid 22 of mixer tube 4 the sum frequency energy which at any setting of the tuning means 6 is equal to the selected local oscillation frequency plus the harmonic energy fed to grid 36. The frequency deviation range is equal to 100 kc.

In the system of Fig. 3 the frequencies of the heterodyning oscillations are below the FM wave frequencies. It is necessary, therefore, to feed the signal energy to mixer 4 with the sum frequencies developed at the output of tube 8. Where the heterodyne oscillations are higher in frequency than the received signals, it is necessary to use the resultant of the heterodyne oscillator minus the fourth harmonic energy. In general, it is more desirable to use the lower oscillatory frequency (37.8 to 45.6 mc.), since the same percentage stability results in a lower number of cycles which the oscillator can drift or wander.

Generically, therefore, I have provided a novel method of frequency deviation reduction in superheterodyne reception of FM waves. My method involves the use of a locked-in oscillator operating in response to the I. F. energy to provide harmonic energy of a proportionately increased deviation range. The harmonic energy is mixed with local oscillations to provide heterodyne FM wave energy. The latter is mixed with the original FM wave energy of wide deviation range to produce the I. F. energy whose deviation range is the difference between the deviation ranges of the mixed FM energies.

While I have indicated and described several systems 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 organizations 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 mixer having an input circuit upon which is applied received angle modulated carrier wave energy of a predetermined center frequency and a relatively wide frequency swing, a source of local oscillations relatively lower in frequency than said center frequency, a demodulator of angle modulated wave energy, a beat frequency network coupled to said mixer output circuit, said beat frequency network being constructed to pass modulated wave energy whose center frequency is substantially reduced from the received modulated energy and whose frequency swing is also reduced, a locked-in oscillator coupled to the output of the beat frequency network and feeding its output oscillations to said demodulator, means for deriving harmonic energy from said last-mentioned oscillator, means mixing the harmonic energy and the local oscillations to provide heterodyne, angle-modulated, energy whose center frequency differs from said original received center frequency by the value of the frequency of said beat network, and means for applying the heterodyne energy to said first mixer.

2. A method of receiving frequency modulated waves in a superheterodyne system, comprising deriving intermediate frequency energy from the received waves, converting the energy into oscillations of double frequency and double the frequency swing of the intermediate frequency energy, mixing the oscillations with unmodulated oscillations of a predetermined frequency value to provide heterodyne frequency modulated energy whose center frequency differs from the received wave center frequency by the intermediate frequency, and mixing the heterodyne

modulated energy and the received waves to provide said intermediate frequency energy.

3. A method of receiving frequency modulated waves in a superheterodyne system, comprising deriving intermediate frequency energy from the received waves, converting the intermediate frequency energy into oscillations of double frequency and double the frequency swing of the intermediate frequency swing, mixing the oscillations with unmodulated oscillations of a predetermined frequency value to provide heterodyne frequency modulated energy whose center frequency differs from the received wave center frequency by the intermediate frequency, mixing the heterodyne modulated energy and the received waves to provide said intermediate frequency energy, producing oscillations whose center frequency is a predetermined sub-multiple harmonic of the intermediate frequency value and whose frequency swing is reduced to a proportional degree, and demodulating the sub-multiple harmonic oscillations.

4. In a superheterodyne receiver of frequency modulated carrier waves of the type employing a locked-in oscillator prior to the demodulator; the method which includes reducing the mean frequency of received waves and concurrently reducing the frequency swing of the waves, operating said oscillator in response to the frequency-reduced energy, controlling the said frequency reduction and concurrent frequency swing reduction in response to said locked-in oscillations and directly demodulating the locked-in oscillations independently of said controlling step.

5. In a superheterodyne receiver of frequency modulated carrier waves of the type employing a locked-in oscillator prior to the demodulator; the method which includes frequency-reducing the mean frequency of received waves and concurrently reducing the frequency swing of the waves, operating said oscillator in response to the frequency-reduced energy, controlling the said frequency reduction and concurrent frequency swing reduction in response to said locked-in oscillations, further frequency-reducing the locked-in oscillations with concurrent proportional frequency swing reduction, and demodulating the last-named frequency-reduced oscillations.

6. In combination, a mixer having an input circuit upon which is applied received angle modulated carrier wave energy of a predetermined center frequency and a relatively wide frequency swing, a source of local oscillations relatively lower in frequency than said center frequency, a demodulator of angle modulated wave energy, an intermediate frequency network coupled to said mixer output circuit, said network being constructed to pass modulated wave energy whose center frequency is substantially reduced from the received modulated energy and whose frequency swing is reduced to the same degree, an oscillator coupled to the intermediate network and feeding its output oscillations to said demodulator, means for deriving harmonic energy from the oscillator, means mixing the harmonic energy and local oscillations to provide heterodyne, angle modulated, energy whose center frequency differs from said original received center frequency by the value of the intermediate frequency, and means for applying the heterodyne energy to said first mixer.

7. A method of receiving frequency modulated waves of the order of 42 to 50 megacycles in a superheterodyne system, comprising deriving intermediate frequency energy of about 8.33 megacycles from the received waves, producing oscillations of double frequency and double the frequency swing of said intermediate frequency, mixing the oscillations with unmodulated oscillations of a predetermined frequency value to provide heterodyne frequency modulated energy whose center frequency differs from the received wave center frequency by the intermediate frequency, mixing the heterodyne modulated energy and the received waves to provide said intermediate frequency energy.

8. A method of receiving frequency modulated waves of 42 to 50 mc., in a superheterodyne system, comprising deriving intermediate frequency energy of 8.33 mc. from the received waves, converting the intermediate frequency energy into oscillations of double frequency and double the frequency swing of the intermediate frequency energy, mixing the oscillations with unmodulated oscillations of a predetermined frequency value to provide heterodyne frequency modulated energy whose center frequency differs from the received wave center frequency by the intermediate frequency, mixing the heterodyne modulated energy and the received waves to provide said intermediate frequency energy, deriving oscillations from the intermediate energy whose center frequency is a predetermined sub-multiple harmonic of the intermediate frequency value, and demodulating the sub-multiple harmonic oscillations.

9. In a superheterodyne receiver of frequency modulated carrier waves of the type employing a locked-in oscillator prior to the demodulator; the method which includes frequency-reducing the mean frequency of received waves and concurrently reducing the frequency swing of the waves, directly applying to said locked-in oscillator said frequency-reduced energy thereby further frequency reducing the modulated carrier waves with concurrent proportional frequency swing reduction, and demodulating the further frequency-reduced waves derived directly from said locked-in oscillator.

10. In a method as defined in claim 9, the additional step of deriving from the locked-in oscillations an harmonic thereof, and employing the harmonic energy in the said first frequency reduction.

11. In combination, in a superheterodyne receiver, a mixer having an input circuit upon which is applied received angle modulated carrier wave energy of a predetermined center frequency chosen from 42 to 50 megacycles and a relatively wide frequency swing of about 150 kilocycles, a source of local oscillations relatively lower in frequency than said center frequency, a demodulator of angle modulated wave energy, an intermediate frequency network coupled to said mixer output circuit, said intermediate network being constructed to pass modulated wave energy whose center frequency is substantially reduced from the received modulated energy to about 8.33 megacycles and whose frequency swing is reduced to about 50 kilocycles, a locked-in oscillator coupled to the intermediate network and feeding its output oscillations to said demodulator, means for deriving second harmonic energy from the oscillator, means mixing the second harmonic energy and local oscillations to provide heterodyne angle modulated energy whose center frequency differs from said original received center frequency by the value of the intermediate frequency of said network, and means for applying the heterodyne energy to said first mixer.

12. A system of receiving frequency modulated waves comprising means deriving intermediate frequency energy from the received waves, means converting the intermediate frequency energy into oscillations of double frequency and double the frequency swing of said intermediate frequency energy, means mixing the oscillations with unmodulated oscillations of a predetermined frequency value to provide heterodyne frequency modulated energy whose center frequency differs from the received wave center frequency by the intermediate frequency, means mixing the heterodyne modulated energy and the received waves to provide said intermediate frequency energy, means deriving oscillations from the intermediate energy whose center frequency is a predetermined sub-multiple harmonic of the intermediate frequency value and whose frequency swing is reduced to a proportional degree, and means for demodulating the sub-multiple harmonic oscillations.

13. In a superheterodyne receiver of frequency modulated carrier waves provided with a locked-in oscillator prior to a demodulator; the method which includes receiving frequency modulated carrier waves of a relatively wide frequency deviation range, reducing the received modulated carrier waves to an intermediate frequency, applying intermediate frequency energy to said oscillator to provide locked-in oscillations of a substantially narrowed deviation range, demodulating the locked-in oscillations, deriving from the locked-in oscillations harmonic energy of a proportionately increased deviation range, controlling the frequency reduction of said received waves in response to said harmonic energy so as to cause said narrowed deviation range to be equal to the difference between said wide deviation range and said harmonic deviation range.

14. In a superheterodyne receiver of frequency modulated carrier waves provided with a locked-in oscillator prior to a demodulator; the method which includes receiving frequency modulated carrier waves of a relatively wide frequency deviation range, reducing the received modulated carrier waves to an intermediate frequency, applying intermediate frequency energy to said oscillator to provide locked-in oscillations of a substantially narrowed deviation range, demodulating a sub-multiple harmonic of the locked-in oscillations with proportionately reduced deviation range, deriving from the locked-in oscillations harmonic energy of a proportionately increased deviation range, controlling the frequency reduction of said received waves in response to said harmonic energy so as to cause said narrowed deviation range to be equal to the difference between said wide deviation range and said harmonic deviation range.

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