Jan. 16, 1945. P. F. G. HOLST ET AL 2,367,352

FREQUENCY MODULATED CARRIER WAVE RECEIVER

Filed Dec. 6, 1941 2 Sheets-Sheet 1

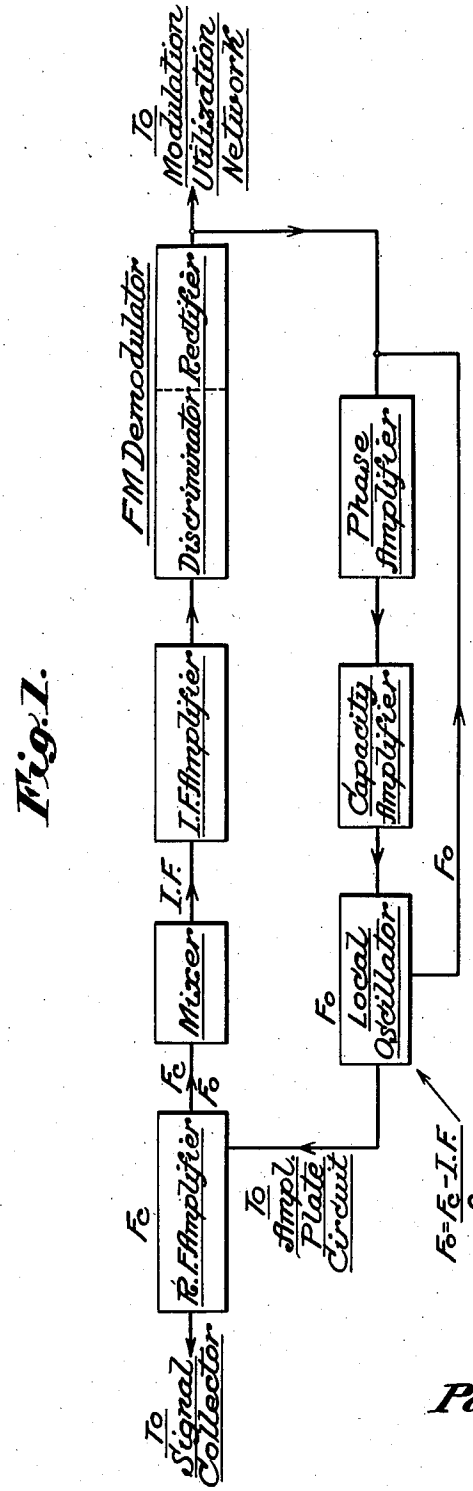


Fig. 1.

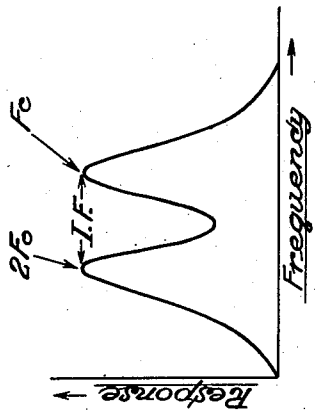


Fig. 3.

INVENTORS
Paul F. G. Holst, Loren R. Kirkwood
BY H. G. Grover
ATTORNEY

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FREQUENCY MODULATED CARRIER WAVE RECEIVER

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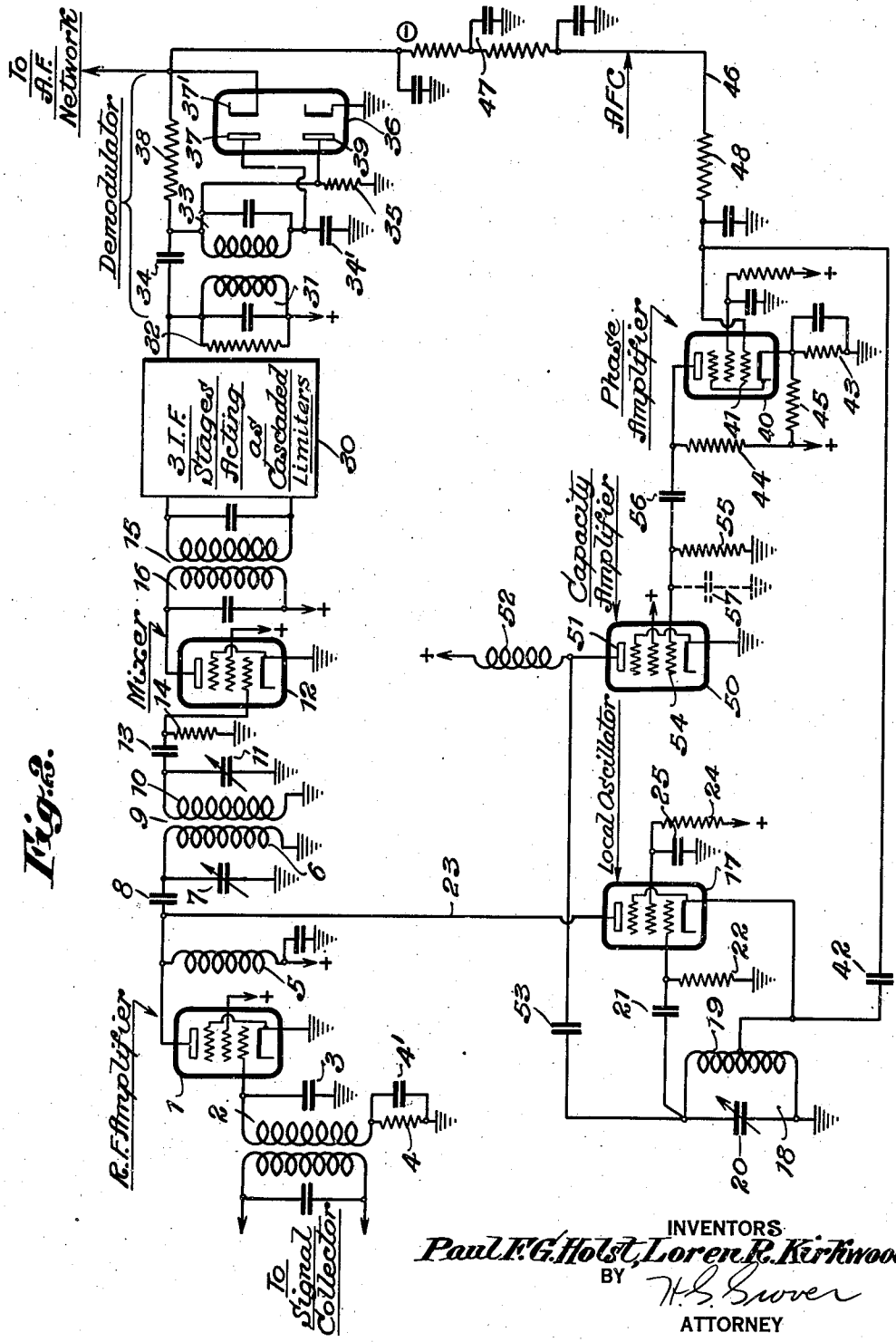


Fig. 2.

INVENTORS
Paul F. G. Holst, Loren R. Kirkwood
BY
H. S. Sowers
ATTORNEY

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2,367,352

FREQUENCY MODULATED CARRIER WAVE RECEIVER

Paul F. G. Holst and Loren R. Kirkwood, Oaklyn, N. J., assignors to Radio Corporation of America, a corporation of Delaware

Application December 6, 1941, Serial No. 421,900

11 Claims. (Cl. 250—20)

Our present invention relates to receivers of angular velocity-modulated carrier waves, and more particularly to receivers of frequency modulated carrier waves.

One of the main objects of our present invention is to provide a frequency modulated carrier wave (FM) receiver of the superheterodyne type utilizing a local oscillator operating at a sub-multiple frequency of the local oscillation frequency actually applied to the mixer, and both local oscillation and signal energies being applied to the mixer from a circuit prior to the mixer input circuit.

Another important object of our invention is to provide in a heterodyne receiver of angular velocity-modulated carrier waves, a local oscillator operating at a frequency equal to one-half the difference between the center frequency of the received waves and the operating intermediate frequency (I. F.) value.

Another important object of our invention is to provide a superheterodyne receiver of modulated carrier waves having an automatic frequency control (AFC) arrangement for controlling the local oscillator frequency over a narrow band of frequencies; the oscillator being of a relatively low radio frequency compared to the signal carrier wave frequency range whereby a more accurate AFC action is secured.

Another object of the invention is to provide an AFC system for a local oscillator; the system comprising a two-tube reactance circuit associated with the oscillator tank circuit to control the frequency thereof.

Yet another object of the invention is to provide a novel method of, and means for, mixing signals to produce a heterodyne frequency; the method involving the injection into the output circuit of a signal amplifier of local oscillations whose frequency is an harmonic of the local oscillator fundamental frequency, and the response characteristic of the network feeding the mixer from the said amplifier output circuit having spaced peaks separated by the I. F. value.

Another object of our invention is to provide an FM receiving system adapted for use in receiving FM waves in a range of 70.4 to 72.6 megacycles (mc.), and the operating I. F. value being of the order of 5 mc., a local oscillator being provided in the system to heterodyne with said waves, said oscillator having a frequency equal to one-half the difference between the center frequency of desired FM waves and the said I. F.

Still other objects of our invention are to improve the efficiency and reliability of FM receivers, and more especially to provide an FM receiver of reliable construction which is capable of economical manufacture and assembly.

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 drawings in which we have indicated diagrammatically a circuit organization whereby our invention may be carried into effect.

In the drawings:

Figure 1 shows a schematic diagram of a receiver embodying the invention;

Figure 2 shows the circuit details of the receiver;

Figure 3 is the frequency response characteristic of the network between the radio frequency amplifier and the mixer.

Referring, now, to the accompanying drawings, wherein like reference characters in the figures designate similar circuit elements, in Figure 1 there is shown the generalized networks of our novel FM receiver. It will be understood that we are not limited to receiving FM waves, as phase modulated waves could be received. Hence, the generic expression "angular velocity-modulated carrier wave" is employed herein to include both of the aforesaid forms of modulation. While FM reception is employed by way of illustration, it will be understood that the invention is not limited thereto, since features thereof may be used in amplitude modulated (AM) carrier wave reception. Further, it is to be understood that the receiver may be employed in frequency ranges other than 70.4 to 72.6 mc., and that the I. F. value can be other than 5 mc. The carrier frequency deviation ratio may be high, say of the order of 50 kilocycles (kc.) to each side of the center frequency (F_c). Of course, where desirable a higher or lower deviation ratio may be employed.

In Figure 1, the collected signals with the center frequency F_c are applied to a radio frequency amplifier. A local oscillator produces oscillations of frequency F_o. These oscillations are fed to the output circuit of the amplifier. The value of F_o is one-half of F_c—I. F. Between the radio amplifier and the mixer network is employed a circuit whose frequency response is double-peaked, as shown in Figure 3. Peak $2F_o$ is of a frequency equal to the second harmonic of F_o. Peak F_c is the desired center frequency. The peaks are spaced by the value of the I. F.

The I. F. output of the mixer is amplified, and subjected to FM demodulation. The demodulator embodies the usual discriminator section to translate the FM waves into AM waves at the I. F. value. The rectifier derives from the AM waves, modulation voltage and direct current voltage. The former corresponds to the modulation originally used to vary the carrier frequency at the transmitter. The latter is used by the AFC circuit to control the oscillator frequency in a sense to maintain the I. F. value at its predetermined magnitude.

The oscillator is operated at a relatively low radio frequency, of the order of half the ultimate heterodyning frequency, to facilitate AFC action. A two-stage reactance simulation network is employed for correcting the frequency of the oscillator tank circuit. A capacity effect is provided across the tank circuit by feeding oscillatory energy F_o to a phase amplifier. The output of the phase amplifier is fed to a capacity amplifier which provides the capacity effect across the tank circuit. The magnitude of the capacity effect, as well as the sense of magnitude change, is controlled by the AFC bias which is applied to the phase amplifier.

In Figure 2 there is shown the specific circuit details of the system schematically represented in Figure 1. The radio frequency amplifier comprises a tube 1 whose cathode is grounded, and whose control grid is connected to the high potential side of the input circuit 2. The input circuit comprises a band pass tuned primary-tuned secondary transformer, in which both circuits are fixedly tuned and have been adjusted to cover the ultra-high frequency tuning range which has been previously referred to. In other words, the input is a band pass link circuit covering the entire band. The low potential side of the input circuit may include a series resistor 4 which is by-passed by condenser 4' for carrier currents. Any desired type of signal collector device, or transmission line, may be coupled to the input coil of circuit 2 provided its characteristic impedance is matched correctly. Such a signal collector device may consist of a dipole, loop, or an ultra-high radio frequency transmission line. In any event, it will be understood that the antenna circuit and input circuit 2 have a frequency response characteristic which is sufficiently wide to pass substantially all the modulated carrier waves of the entire band. The network 4—4' may provide amplitude limiting action to minimize input circuit loading.

The plate of pentode tube 1 is preferably connected to the positive terminal of the direct current voltage supply source. The connection is made through a radio frequency choke coil 5 whose lower end is by-passed to ground for radio frequencies by a by-pass condenser. The output load impedance of amplifier tube 1 comprises a parallel resonant circuit consisting of coil 6 and adjustable condenser 7. The high potential side of resonant circuit 7—6 is connected to the plate end of coil 5 by a direct current blocking condenser 8. The low potential ends of condenser 7 and coil 6 are established at an invariable radio frequency potential. The coil 6 is the primary winding of a transformer 9 whose secondary winding 10 is shunted by the variable tuning condenser 11.

The high potential ends of coil 10 and condenser 11 are coupled to the input grid of the following mixer tube 12 by the condenser 13. The low potential ends of the coil 10 and variable condenser 11 are also established at an invariable radio frequency potential. The mixer, or first detector, tube 12 may also be of the pentode type, and may be similar to tube 1. The cathode of tube 12 is established at ground potential, while the control grid thereof is connected to ground through the grid leak resistor 14. The plate of the mixer tube is connected to the proper positive terminal on the direct current voltage supply through the primary winding of the I. F. transformer 15. The primary resonant circuit 16 is fixedly tuned to the operating I. F. value. The latter, as stated before, is of the order of 5 mc.

As indicated previously, the network 7—6, 10—11 is so constructed and designed that it has the frequency response characteristic shown in Figure 3. It will be observed from that characteristic that the tuned primary and secondary circuits of transformer 9 are sufficiently overcoupled to provide the double-peaked curve with the deep valley between the peaks. The left peak is located at a frequency which is the second harmonic of F_o, the latter being the value of the frequency of the local oscillator. The second peak is located at the center frequency F_c of the selected modulated carrier waves. The peaks are spaced by a frequency value equal to the I. F. Hence, it will be seen that when the receiver is adjusted to receive a desired value of F_c of a given FM channel, then the condensers 7, 11 and 20 are concurrently adjusted so that for any adjustment of the tuning condensers there will be produced FM waves across the I. F. output circuit 16 whose center frequency is of the operating I. F. value.

Referring now to the local oscillator, it will be seen that that stage comprises a pentode tube 17 which may be the same type of tube as 1 and 12. The tunable tank circuit is designated by numeral 18, and comprises a coil 19 shunted by variable tuning condenser 20. The high potential side of tank circuit 19—20 is connected by the grid condenser 21 to the control grid of tube 17, the grid leak resistor 22 connecting the control grid to ground. The low potential side of tank circuit 18 is established at an invariable radio frequency potential. The cathode of tube 17 is connected to an appropriate intermediate point on the tank coil 19.

The plate of tube 17 is connected by lead 23 to the plate end of choke coil 5. Hence, it will be seen that both the plates of the radio frequency amplifier tube 1 and the oscillator tube 17 are provided with positive voltage from a common source. It will, also, be recognized that the oscillator is of the familiar Hartley type. The screen grid of tube 17 is connected to the source of positive direct current voltage through a resistor 24, the upper end of which is by-passed to ground by a condenser 25.

The tank circuit 18 is tuned to F_o. As stated previously, F_o is equal to a value which is one half F_c—I. F. It will be understood that when the tuning condensers 7 and 11 are adjusted concurrently to a given value of F_c, then simultaneously the tuning condenser 20 will be adjusted to that value of F_o which will constantly provide the operating I. F. value. From the circuit shown, it will be appreciated that the local oscillatory energy is injected by lead 23 into the output circuit of the amplifier 1. This is quite contrary to the usual practice, wherein the local oscillations are applied directly to an electrode of the first detector tube.

It was decided to operate the local oscillator at one half the frequency of the energy actually mixed with the signal energy, because it has been found that the difficulty encountered in controlling the frequency of the local oscillator becomes the greater the higher the local oscillator frequency. While the oscillator circuit is generally of the Hartley type, it differs from the conventional Hartley circuit in that the screen electrode has been by-passed to ground, while in the plate circuit of the oscillator tube an impedance network has been inserted. This impedance network may generally be considered the network 7—6, 10—11.

An action of the aforesaid impedance network is to cause the voltage developed thereacross to be twice the frequency of the oscillatory energy fed through lead 23. The untuned radio frequency choke coil 5, as stated before, supplies the plates of the oscillator tube and radio frequency amplifier tube in parallel. Inasmuch as both tubes are pentodes, the loading effect of each one on the other is negligible. Another way of considering the impedance provided in the plate circuit of the oscillator tube 17 is by referring to the left peak in the response characteristic of Figure 3. It may be stated that the impedance in the plate circuit of the oscillator tube corresponds to the peak $2F_0$ in the complete coupling network between the radio frequency amplifier tube 1 and the input electrodes of the mixer tube 12.

The I. F. energy output of circuit 16 is transmitted through an I. F. amplifier network which may comprise a plurality of cascaded I. F. amplifier tubes. For example, each of the I. F. amplifier tubes may be of the 6SH7 type. Each amplifier functions as a limiter so as to minimize amplitude modulation effects which may exist on the carrier. The numeral 30 designates the I. F. amplifier network, and it will be understood that the network may be constructed in the same manner as is disclosed and claimed in our application Serial No. 421,286, filed Dec. 2, 1941.

The output voltage of the I. F. amplifier network 30, whose AM components have been substantially eliminated by virtue of the limiting action of network 30, is applied to the demodulator network. The demodulator, which may be of any well known and desirable type, functions in a manner well known to those skilled in the art. The discriminator section of the demodulator converts the FM waves into AM waves. The AM waves are rectified by any rectifier device to provide the modulation voltage and the AFC bias. The specific demodulator network shown in Fig. 2 may be of the general type disclosed and claimed by E. A. Green in U. S. Patent 2,248,229 granted July 8, 1941. There also may be used demodulator networks of the type shown by John D. Reid in application Serial No. 353,028 filed August 17, 1940.

More specifically, we prefer to utilize a demodulator network of the type shown in the aforesaid Reid application. The numeral 31 denotes the resonant primary circuit arranged in the output of the last I. F. amplifier. This circuit is tuned to the operating I. F. value, and has in shunt therewith a resistor 32 to provide proper damping of the circuit. The secondary circuit is designated by numeral 33, and the high potential side of circuit 33 is connected to the high potential side of circuit 31 by the coupling condenser 34. The low potential side of circuit 33 is connected to ground through condenser 34'. The capacitative magnitudes of condensers 34 and 34' are equal.

The high potential side of circuit 33 is also connected to ground through a resistor 35. The rectifier of the demodulator network consists of the double diode tube 36 which may be of the 6H6 type. The anode 37 of one of the diodes is connected to the ungrounded terminal of condenser 34', while the cathode 37' is connected to the high potential side of circuit 33 through a resistor 38. The anode 39 of the second diode of tube 36 is connected to the ungrounded end of resistor 35, while the cathode of that diode is established at ground potential.

The primary circuit 31 is overcoupled to the secondary which consists of 33—34 and 34'. The impedance characteristic of the network will, therefore, be a double-peaked response curve with a dip at the 5 mc. I. F. value. Circuit 33 resonates at 5.1 mc. Circuit 33 and 34' in series resonate at 4.9 mc. The elements 34—33—34' in series resonate at 5 mc. The alternating voltage across 33 and 34' in series is rectified by diode 39 thereby causing negative direct current voltage to appear across resistor 35. Likewise, the voltage across 34' is rectified by diode 37 and the resultant positive voltage appears across resistor 38. Hence, if the I. F. energy mid-band frequency is at 5 mc., the voltages across 35 and 38 are medium and the AFC bias is zero. If the mid-band frequency is below 5 mc., the voltage across 38 is high and the AFC bias is positive. If the mid-band frequency is above 5 mc., the negative voltage across resistor 35 predominates and the AFC bias is negative.

The discriminator-rectifier is of the single-ended type. The modulation voltage is taken off from the cathode end of resistor 38, and may be used in any subsequent audio utilization network. The AFC bias is also derived from the cathode end of resistor 38. It is desirable, for a reason to be explained at a later point, that the AFC bias have a negative polarity when the mid-band frequency of the I. F. energy developed across circuit 31 is higher than the predetermined operating I. F. value.

There will now be considered the manner in which frequency correction is applied to the oscillator tank circuit 18. A portion of the local oscillator energy is taken off from the cathode tap on tank coil 19, and the energy is impressed upon the control grid of a pentode 40. The oscillatory energy is transmitted to the control grid 41 through a path including the coupling condenser 42. The tube 40 functions as a phase amplifier, and there is also applied to its grid 41 the AFC bias. The cathode of tube 40 is connected to ground through a grid biasing network 43, and the plate of tube 40 is connected to a point of proper positive potential on the direct current voltage supply through a plate resistor 44. The lower end of resistor 44 is connected by resistor 45 to the cathode end of the biasing resistor 43. The AFC lead is designated by numeral 46, and includes a filter network comprising a pair of series related resistors shunted to ground by by-pass condensers. The function of the filter 47 is to suppress audio currents in the AFC lead. The network 48 acts to prevent the audio filter capacitor from loading the input network of tube 40.

A second tube 50, which may be of the same pentode type as tube 40, has its cathode established at an invariable alternating potential. The plate 51 of tube 50 is connected to a source of positive potential through the radio frequency

choke coil 52. The plate end of coil 52 is connected to the high potential side of tank circuit 18 by the coupling condenser 53. Hence, it will be seen that the plate to cathode impedance of tube 50 is connected across the tank circuit 18. This tube impedance simulates a capacitative reactance, and, hence, the expression "capacity amplifier" is used in connection with the function of tube 50. The tube 50 actually functions to amplify a capacitative reactance effect applied to the input electrodes of the tube. The control grid of tube 50 is denoted by numeral 54, and the latter is connected to ground through the grid leak resistor 55. The grid side of resistor 55 is connected to the plate end of resistor 44 by the direct current blocking condenser 56. The numeral 57 designates the capacity which is the principal plate load in tube 40.

In considering the action of the frequency correction network, it is first pointed out that by virtue of a low plus B voltage employed on the plate of the oscillator tube together with the relatively high oscillator frequency, there is required a two tube circuit in the correction network in order to obtain sufficient reactance control. A fraction of the oscillator voltage existing between the oscillator coil tap and ground is obtained by means of a capacity bleeder and is fed to the control grid 54 of the fixed-bias "phase amplifier" tube 40. The resistor 45 is used to provide semi-fixed bias in tube 40. The plate current in tube 40 will be in phase with the input voltage, but inasmuch as the load in the plate circuit (due to tube and distributed capacitance) is almost pure capacitance, it follows that the voltage impressed on the grid 54 of tube 50 will be 90 degrees ahead of the grid voltage in tube 40. Therefore, the plate current drawn by the capacity amplifier tube 50 will be 90 degrees ahead of the alternating current plate voltage of the same tube, and this voltage-to-current relation denotes a capacitative load on the tank circuit 18.

If the gain of the phase amplifier tube 40 is varied by adjustment of the control grid bias, it will be seen that the effective capacitance load of tube 50 will vary. More specifically, if the bias applied to grid 41 is made more negative, the capacitative load of tube 50 will decrease, and the local oscillator frequency will increase. Since the oscillator frequency is lower than the signal frequency, an increase in oscillator frequency will result in a decrease of the operating I. F. value. It is, therefore, necessary that the demodulator circuit be designed in a manner which will cause I. F. energy to produce a negative AFC bias when its mid-band frequency is higher than the operating I. F. value. In prior circuits of the single-ended discriminator type a positive AFC bias is usually produced when the mid-band frequency of the I. F. energy is higher than the operating I. F. value. Hence, the discriminator-rectifier sections of the present demodulator network have been designed in the present circuit so as to provide a negative AFC bias when the mid-band frequency of the I. F. energy is higher than the operating I. F. value.

It has been found that the AFC circuit disclosed herein is of advantage in a system wherein the voltage regulation on the oscillator tube is poor. The AFC circuit functions in a highly satisfactory manner and regulates the tank frequency in such a manner that the operating I. F. value is maintained substantially constant. The principal objects which made it desirable to add an AFC circuit to this receiver are in order of their importance:

(1) Ease of tuning.

(2) Overcome the effects of transmitter frequency drift,

(3) Overcome the effects of receiver oscillator frequency drift.

If the power supply source is a storage battery source which gradually becomes weaker after the passage of time, the AFC acts to overcome oscillator frequency drift. The power supply source may be the usual power rectifier for operation with a commercial alternating current source. It is, also, pointed out that the present AFC system is of particular advantage in the case of a mobile receiver unit which is encased in a housing which does not permit ready change of any battery source. In such case the AFC circuit must function to maintain a high degree of correction in spite of considerable variation of the direct current voltage supply.

While we have indicated and described a system 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 organization 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 modulated carrier wave receiving system of the heterodyne type, a mixer stage provided with an output circuit tuned to a desired heterodyne frequency, a signal amplifier stage, a local oscillator stage tuned to a frequency which is equal to one half the difference between the desired signal frequency and said heterodyne frequency, a reasonant network having a double peaked response curve coupling the output electrodes of said signal amplifier stage and the mixer input electrodes, means for injecting the oscillatory output of said oscillator stage into the input of said coupling network, and said coupling network response curve having one peak at double the frequency of the oscillations produced by said oscillator stage and the second peak at the signal carrier frequency.

2. In a modulated carrier wave receiving system of the heterodyne type, a mixer stage provided with an output circuit tuned to a desired heterodyne frequency, a signal amplifier stage, a local oscillator stage tuned to a frequency which is equal to one half the difference between the desired signal frequency and said heterodyne frequency, a resonant network coupling the output electrodes of said signal amplifier stage and the mixer input electrodes, means for injecting the oscillatory output of said oscillator stage into the input of said coupling network, and said coupling network having a frequency response characteristic with spaced peak frequencies at values equal to double oscillator frequency and the desired signal frequency.

3. In a modulated carrier wave receiving system of the heterodyne type, a mixer stage provided with an output circuit tuned to a desired heterodyne frequency, a signal amplifier stage, a local oscillator stage tuned to a frequency which is equal to substantially one half the difference between the desired signal frequency and said heterodyne frequency, a resonant network coupling the output electrodes of said signal amplifier stage and the mixer input electrodes, means for injecting the oscillatory output of said oscillator stage into the said coupling network,

said coupling network being constructed to double the frequency of the oscillations produced by said oscillator stage, and means, responsive to a shift of the heterodyne energy from said predetermined heterodyne frequency, for adjusting said oscillator stage frequency in a sense to maintain said heterodyne energy at said desired heterodyne frequency and said oscillator stage frequency being of a sufficiently low radio frequency to facilitate said oscillator frequency adjusting action.

4. In a modulated carrier wave receiving system of the heterodyne type, a mixer stage provided with an output circuit tuned to a desired heterodyne frequency, a signal amplifier stage, a local oscillator stage tuned to a frequency which is equal to one half the difference between the desired signal frequency and said heterodyne frequency, a resonant network coupling the output electrodes of said signal amplifier stage and the mixer input electrodes, means for injecting the oscillatory output of said oscillator stage into the input of said coupling network, said coupling network having an output circuit whose impedance is such as to double the frequency of the oscillations produced by said oscillator stage, said coupling network consisting of an overcoupled pair of tuned circuits having a double peaked response curve whose peak frequencies are spaced by the value of said heterodyne frequency, said signal amplifier stage having a source of angular velocity-modulated carrier waves coupled to its input electrodes, and a heterodyne amplifier network coupled to the mixer output circuit, said heterodyne amplifier network additionally functioning to minimize amplitude modulation effects on the received carrier waves.

5. In a frequency modulated carrier wave receiving system of the heterodyne type, a converter provided with an output circuit tuned to a desired heterodyne frequency, a signal amplifier stage, a local oscillator stage tuned to a frequency which is equal to one half the difference between the desired signal frequency and said heterodyne frequency, a resonant network coupling the output electrodes of said signal amplifier stage and the converter input electrodes, means for applying the oscillatory output of said oscillator stage to said coupling network, said coupling network being constructed and arranged to double the frequency of the oscillations produced by said oscillator stage and said coupling network consisting of a pair of tuned circuits overcoupled to provide a double peaked response curve whose peak frequencies are separated by the value of the heterodyne frequency.

6. In a frequency modulated carrier wave receiving system of the superheterodyne type, a first detector stage provided with an output circuit tuned to a desired intermediate frequency, a signal amplifier stage, a local oscillator stage tuned to a relatively low radio frequency, a resonant network coupling the output electrodes of said signal amplifier stage and the first detector input electrodes, means for injecting the oscillatory output of said oscillator stage into the said coupling network, said coupling network having an impedance such as substantially to increase the frequency of the oscillations produced by said oscillator stage, and said coupling network having a frequency response characteristic with spaced peaked frequencies whose values are respectively the desired signal carrier frequency and the increased oscillation frequency.

7. In a frequency modulated carrier wave receiving system of the heterodyne type, a mixer stage provided with an output circuit tuned to a desired heterodyne frequency, a signal amplifier stage, a local oscillator stage tuned to a frequency which is equal to one half the difference between the desired signal frequency and said heterodyne frequency, a resonant network coupling the output electrodes of said signal amplifier stage and the mixer input electrodes, means for injecting the oscillatory output of said oscillator stage into the input of said coupling network, said coupling network having an output circuit whose impedance is such as to double the frequency of the oscillations produced by said oscillator stage, means, responsive to a shift of the heterodyne energy from said predetermined heterodyne frequency, for adjusting said oscillator stage frequency in a sense to maintain said heterodyne energy at said desired heterodyne frequency, said last means including a pair of tubes functioning to provide a capacitative reactance across the oscillator and said oscillator stage frequency being of a sufficiently low radio frequency to facilitate said oscillator frequency adjusting action.

8. In a modulated carrier wave receiving system of the heterodyne type, a mixer stage provided with an output circuit tuned to a desired heterodyne frequency, a signal amplifier stage, a local oscillator stage tuned to a frequency which is equal to one half the difference between the desired signal frequency and said heterodyne frequency, a resonant network coupling the output electrodes of said signal amplifier stage and the mixer input electrodes, means for injecting the oscillatory output of said oscillator stage into the input of said coupling network, said coupling network being constructed and arranged to provide a double peaked response curve having its spaced peak frequencies separated by said heterodyne frequency, said signal amplifier stage having a source of angular velocity-modulated carrier waves coupled to its input electrodes, a heterodyne amplifier network coupled to the mixer output circuit, said heterodyne amplifier network additionally functioning to minimize amplitude modulation effects on the received carrier waves.

9. In a modulated carrier wave receiving system of the heterodyne type, a mixer stage provided with an output circuit tuned to a desired heterodyne frequency, a signal input network, a local oscillator stage tuned to a radio frequency which is relatively lower than the signal frequency, a resonant network having input and output terminals coupling the signal input network and the mixer input electrodes, means for injecting the oscillatory output of said oscillator stage into the input terminals of said coupling network, said coupling network having an impedance such as to double the frequency of the oscillations produced by said oscillator stage and said coupling network consisting of a pair of overcoupled tuned circuits whose response curve is double peaked with spaced peak frequencies at the double frequency and signal frequency respectively.

10. In a signal carrier wave receiving system of the heterodyne type, a mixer stage provided with an output circuit tuned to a desired heterodyne frequency, a signal input source, a local oscillator stage tuned to a frenquency which is equal to one half the difference between the desired signal carrier frequency and said heterodyne frequency, a resonant network coupling said signal source and the mixer input electrodes, means for injecting the oscillatory output of said oscillator stage into said coupling network, said coupling network having an impedance such as to

double the frequency of the oscillations produced by said oscillator stage, and said coupling network having a double peaked frequency response characteristic with spaced peak frequencies at values respectively equal to said double oscillator frequency and the desired signal carrier frequency.

11. In a modulated signal carrier wave receiving system of the heterodyne type, a mixer stage provided with an output circuit tuned to a desired heterodyne frequency, a signal input stage, a local oscillator stage tuned to a frequency which is equal to one half the difference between a desired signal carrier frequency and said heterodyne frequency, a resonant network coupling the said signal output stage and the mixer input electrodes, means for injecting the oscillatory output of said oscillator stage into said coupling network, said coupling network having an impedance such as to double the frequency of the oscillations produced by said oscillator stage, and means, responsive to a shift of the heterodyne energy from said predetermined heterodyne frequency, for adjusting said oscillator stage frequency in a sense to maintain said heterodyne energy at said desired heterodyne frequency and said oscillator stage frequency being of a sufficiently low radio frequency to facilitate said oscillator frequency adjusting action.

PAUL F. G. HOLST.
LOREN R. KIRKWOOD.