June 16, 1942. S. HUNT 2,286,997

FREQUENCY MODULATION CONVERTER

Filed May 15, 1941

Fig. 1.

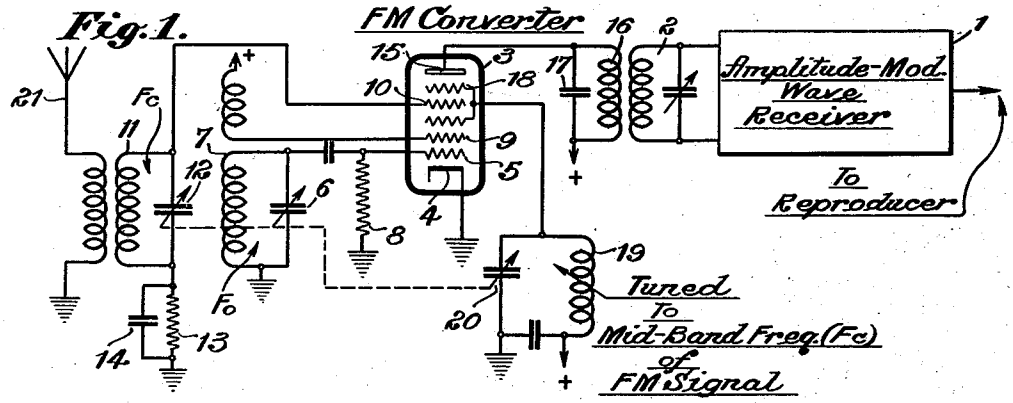


Fig. 2.

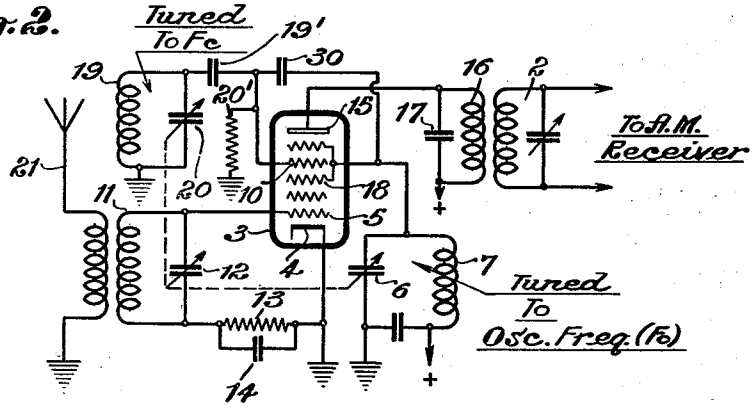
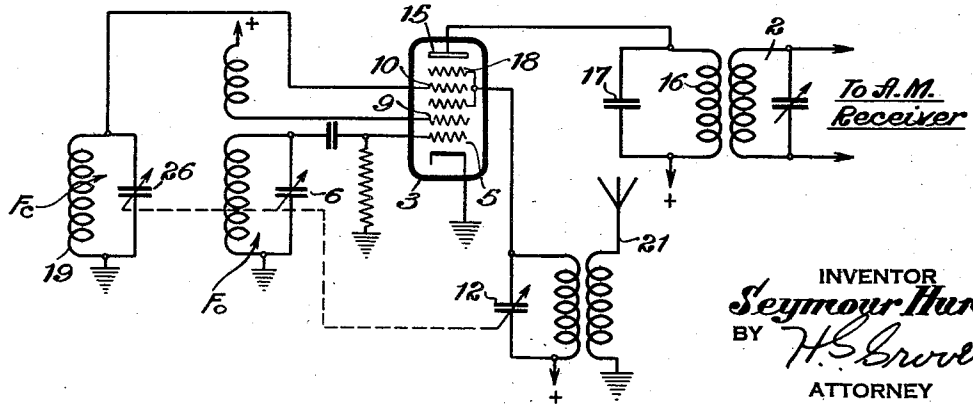


Fig. 3.



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Patented June 16, 1942

2,286,997

UNITED STATES PATENT OFFICE

2,286,997

FREQUENCY MODULATION CONVERTER

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Application May 15, 1941, Serial No. 393,537

14 Claims. (Cl. 250—20)

My present invention relates to converters, or translators, of angular velocity-modulated carrier waves, and more particularly to frequency modulated carrier wave converters.

One of the main objects of my invention is to provide a network capable of simultaneously reducing the center frequency of angular velocity-modulated carrier waves, and translating the resultant waves into amplitude-modulated carrier waves.

Another important object of my invention is to provide an adapter for enabling frequency modulated carrier waves to be received with an amplitude-modulated wave receiver of usual and conventional design.

Another object of the invention is to provide a mixer circuit whose input has applied to it frequency modulated carrier waves, local oscillations being applied to the mixer to reduce the center frequency of the carrier waves to a desired intermediate frequency value, and there being applied to the mixer additional frequency modulated carrier waves in such phase that the reduced carrier waves are of variable amplitude.

Still other objects of my invention are to improve devices for transforming frequency modulated carrier waves into corresponding amplitude-modulated waves, and more especially to provide such transforming devices in an economical and reliable manner.

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

In the drawing:

Fig. 1 shows one arrangement embodying the invention,

Fig. 2 illustrates a modification,

Fig. 3 shows another modification.

Referring now to the accompanying drawing, wherein like reference characters in the different figures designate similar elements, the numeral 1 denotes a conventional amplitude modulated carrier wave receiver. Let it be assumed that receiver 1 is a superheterodyne of known construction, and that it is adapted to be turnable over a wide frequency range. The tunable selector circuit 2 is to be understood as being of the multi-band type. That is, a wave-change switch may be included to enable circuit 2 to be tunable over the 550 to 1700 kilocycle (kc.) band, or the switch may be adjusted to enable the selector to be adjusted over the short wave bands. In any event, it is to be understood that the circuit 2 can be adjusted to tune to frequencies of the order of 2 to 8 megacycles (mc.). Of course, the receiver would include a proper converter to produce the usual 450 kc. intermediate frequency energy, and a demodulator would detect the latter to produce the audio modulation voltage for the reproducer.

To receive frequency modulated carrier waves in the assigned 42 to 50 mc. band, it is then only necessary to select the desired channel and beat the center frequency of the selected frequency modulated wave down to the frequency of circuit 2. Assuming that circuit 2 is adjusted so as to remain fixedly tuned to 4.3 mc., the network denoted "FM converter" is constructed to reduce the center frequency (F_c) to the 4.3 mc. value, while concurrently transforming the constant amplitude-variable frequency wave into a variable amplitude wave.

The tube 3 may be a pentagrid converter tube of the 6A8 type. The cathode 4 is established at ground potential. The oscillator grid 5 is coupled by a blocking condenser to the high potential side of a tunable tank circuit comprising a variable condenser 6 and shunt coil 7. The oscillator tank frequency is represented by symbol F_o. The grid leak resistor 8 returns the gride 5 to ground. The anode electrode 9 is reactively coupled to coil 7 through the usual feedback coil, and there is applied appropriate positive potential to electrode 9. The signal input grid 10 is connected to the high potential side of tunable selector circuit 11—12. The low potential end of the coil 11 is connected to ground through resistor 13 which is by-passed for carrier frequencies by shunt condenser 14. The signal grid 10 is surrounded by a positive screening field. Plate 15 is connected to the high potential end of output coil 16. Shunt condenser 17 tunes coil 16 to the frequency of circuit 2.

The positive screen 18 is connected to the high potential side of a tunable circuit comprising coil 19 and variable tuning condenser 20. Circuit 20—19 is resonated to F_c, and a uni-control means is used to adjust the rotors of variable condensers 12, 6 and 20 in unison. The low potential end of coil 19 is connected to a source of positive potential, and by a direct current blocking condenser to the grounded end of condenser 20.

It will now be seen that the signal collector 21, which may be grounded antenna circuit or a loop or a di-pole, feeds the frequency modulated carrier waves to the selector circuit 11—12. The tuning control (shown by dotted lines) is actuated to adjust 11—12 and 20—19 to the desired F_c value of the FM band. Simultaneously, the tank circuit 7—6 is adjusted to provide such a local oscillation frequency that in output circuit 17—16 there is produced a modulated carrier wave whose mid-band frequency is equal to 4.3 mc. The I.F. energy in the circuit 17—16 is amplitude modulated. Hence, relative to the receiving system 2—1 the applied waves from 17—16 appear as a carrier wave having amplitude modulation and having the carrier frequency to which selector 2 has been adjusted. Thus, a person owning a conventional multi-band receiver may receive FM waves by using the converter shown, and merely fixedly adjusting the receiver signal selector circuit to the I.F. value of the converter output. The oscillator frequency of tank circuit 7—6 may be 4.3 mc. higher or lower than the corresponding F_c value.

The conversion from FM to AM in tube 3 is secured by virtue of the phase quadrature relation between the signal wave at grid 10 and that at grid 18. Applying the FM wave to grid 10 results in developing oscillations in 20—19 of the center frequency F_c. This occurs by virtue of space charge coupling within the tube. In such case the FM waves at 18 are 90 degrees out of phase relative to the waves at grid 10. It has been shown that in such case the current flowing through output circuit 17—16 is of variable amplitude. The modulation on the carrier now appears as a variation in carrier amplitude, whereas in the FM carrier wave the modulation appeared as frequency deviations of the carrier. The network 13—14 gives a degree of noise limiting, since above a predetermined carrier amplitude the grid 10 draws current and builds up across resistor 13 a negative grid bias. It may be desirable to have the network 16—2 as broad as possible (and this may also be true of the receiver circuits prior to the demodulator) so as to be able to pass any frequency modulation that may appear in the reduced carrier at 17—16.

In Fig. 2 there is shown a modification wherein the 6A8 type tube 3 has the circuits thereof arranged differently. Here, the signal input circuit 11—12 is connected between cathode 4 and grid 5. The second grid is not used. The auxiliary F_c circuit 19—20 is connected between grid 10 and ground, the blocking condenser 19' being connected to ground on the grid side thereof by a leak resistor 20'. The latter provides amplitude variation limiting, and thereby supplements the limiting network 13—14. The local oscillations are produced by coupling tank circuit 6—7 to the electrode 18. A condenser 30 connects electrode 18 to grid 10. Oscillations are produced between grid 5 and electrode 18. This type of negative mutual conductance oscillator is described in U. S. Patent 2,051,178, granted August 18, 1936.

The modification in Fig. 3 differs from the arrangement in Fig. 1 in that the signal wave collector 21 is coupled to the electrode 18. Further, the auxiliary tuned circuit 19—26 is coupled to grid 10. It will, therefore, be seen that the F_c circuits are interchanged so far as the arrangement of Fig. 3 is concerned.

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 with a tube provided with a cathode, an output electrode and at least three cold electrodes arranged in the electron stream between the cathode and output electrode, a source of angular velocity modulated carrier waves coupled to one of said cold electrodes, said source supplying waves of a predetermined center frequency, means applying to a second of the cold electrodes angular velocity modulated carrier waves of the aforesaid center frequency, means for applying to the third of said cold electrodes local oscillations having a frequency substantially different from said center frequency, and an output circuit connected to said output electrode and tuned to a frequency which is equal to the difference between said center frequency and said local oscillation frequency.

2. In combination with a tube provided with a cathode, an output electrode and at least three cold electrodes arranged in the electron stream between the cathode and output electrode, a source of angular velocity modulated carrier waves coupled to one of said cold electrodes, said source supplying waves of a predetermined center frequency, means applying to a second of the cold electrodes angular velocity modulated carrier waves of the aforesaid center frequency, means for applying to the third of said cold electrodes local oscillations having a frequency substantially different from said center frequency, and an output circuit connected to said output electrode and tuned to a frequency which is equal to the difference between said center frequency and said local oscillation frequency, the modulated waves applied to the second cold electrode being in substantial phase quadrature with the waves applied to the first electrode, and there being developed across said output circuit amplitude modulated carrier waves whose mid-band frequency is said difference frequency.

3. In combination with a tube provided with a cathode, an output electrode and at least three cold electrodes arranged in the electron stream between the cathode and output electrode, a source of angular velocity modulated carrier waves coupled to one of said cold electrodes, said source supplying waves of a predetermined center frequency, means applying to a second of the cold electrodes angular velocity modulated carrier waves of the aforesaid center frequency, means for applying to the third of said cold electrodes local oscillations having a frequency substantially different from said center frequency, and an output circuit connected to said output electrode and tuned to a frequency which is equal to the difference between said center frequency and said local oscillation frequency, the modulated waves applied to the second cold electrode being in substantial phase quadrature with the waves applied to the first electrode, and there being developed across said output circuit amplitude modulated carrier waves whose mid-band frequency is said difference frequency, and means coupled to said output circuit for deriving from said amplitude modulated carrier wave the modulation voltage thereon.

4. A network, adapted to convert frequency modulated carrier waves to corresponding ampli-

tude modulated carrier waves but with reduced center frequency, comprising an electron discharge tube having an electron emitter and an output electrode, at least three cold electrodes in the electron stream to said output electrode, a tunable selector circuit adapted to impress upon one of said cold electrodes frequency modulated carrier waves of a predetermined center frequency, a second tunable circuit adapted to be resonated to a selected center frequency and connected to a second of said cold electrodes, a tunable oscillator tank circuit operatively associated with the third cold electrode for applying thereto oscillatory voltage whose frequency differs from the aforesaid center frequency by a predetermined intermediate frequency, and an output circuit coupled to said output electrode and tuned to said intermediate frequency.

5. A network, adapted to convert frequency modulated carrier waves to corresponding amplitude modulated carrier waves but with reduced center frequency, comprising an electron discharge tube having an electron emitter and an output electrode, at least three cold electrodes in the electron stream to said output electrode, a tunable selector circuit adapted to impress upon one of said cold electrodes frequency modulated carrier waves of a predetermined center frequency, a second tunable circuit adapted to be resonated to a selected center frequency and connected to a second of said cold electrodes, a tunable oscillator tank circuit operatively associated with the third cold electrode for applying thereto oscillatory voltage whose frequency differs from the aforesaid center frequency by a predetermined intermediate frequency, and an output circuit coupled to said output electrode and tuned to said intermediate frequency, the carrier voltages on said first and second cold electrodes being in phase quadrature at the center frequency, and said amplitude modulated carrier waves whose center frequency is of said intermediate frequency being developed across said output circuit.

6. In combination with a tube provided with a cathode, an output electrode and at least three cold electrodes arranged in the electron stream between the cathode and output electrode, a source of angular velocity modulated carrier waves coupled to one of said cold electrodes, said source supplying waves of a predetermined center frequency, means applying to a second of the cold electrodes angular velocity modulated carrier waves of the aforesaid center frequency, the waves at said first and second cold electrodes being in phase quadrature, means for applying to the third of said cold electrodes local oscillations having a frequency substantially different from said center frequency, and an output circuit connected to said output electrode and tuned to a frequency which is equal to the difference between said center frequency and said local oscillation frequency, said output circuit developing amplitude modulated waves of said difference frequency.

7. A method of receiving frequency modulated carrier waves of a predetermined center frequency which comprises combining said waves with constant frequency waves of a different frequency to produce waves of a lower frequency, and simultaneously beating with said constant frequency waves additional frequency modulated waves of said center frequency but in phase quadrature with the original frequency modulated waves whereby the lower frequency waves are amplitude modulated.

8. In combination with a tube provided with a cathode and at least four cold electrodes arranged in succession in a common electron stream, a source of angular velocity modulated carrier waves coupled to one of said cold electrodes, said source applying waves of a predetermined center frequency, means applying to a second of the cold electrodes angular velocity modulated carrier waves of the aforesaid center frequency which are in substantial phase quadrature with the waves at the said one cold electrode, means for applying to the third of said cold electrodes local oscillations having a constant frequency substantially different from said center frequency, and an output circuit connected to a fourth cold electrode and tuned to a frequency which is equal to the difference between said center frequency and said local oscillation frequency.

9. In combination with a tube provided with a cathode, a plate and at least three grids arranged in the electron stream between the cathode and plate, an input circuit of angular velocity modulated carrier waves of a desired center frequency coupled to one of said grids, means applying to a second of the grids angular velocity modulated carrier waves of the aforesaid center frequency, means for applying to the third of said grids local oscillations having a frequency substantially different from said center frequency, and an output circuit connected to said plate and tuned to a frequency which is equal to the difference between said center frequency and said local oscillation frequency, the modulated waves applied to the second grid being in substantial phase quadrature with the waves applied to the first grid, and there being developed across said output circuit amplitude modulated carrier waves whose mid-band frequency is said difference frequency.

10. A network adapted to convert frequency modulated carrier waves to corresponding amplitude modulated carrier waves but with reduced center frequency, comprising an electron discharge tube having an electron emitter and an output electrode, at least three cold electrodes in the electron stream to said output electrode, a tunable selector circuit adapted to impress upon one of said cold electrodes frequency modulated carrier waves of a predetermined center frequency, means connected to said selector circuit for substantially minimizing amplitude variation of the said carrier waves, a second tunable circuit adapted to be resonated to a selected center frequency and connected to a second of said cold electrodes, a tunable oscillator tank circuit operatively associated with the third cold electrode for applying thereto oscillatory voltage whose frequency differs from the aforesaid center frequency by a predetermined intermediate frequency, and an output circuit coupled to said output electrode and tuned to said intermediate frequency.

11. A network, adapted to convert frequency modulated carrier waves to corresponding amplitude modulated carrier waves but with reduced center frequency, comprising an electron discharge tube having an electron emitter and an output electrode, at least three cold electrodes in the electron stream to said output electrode, a tunable selector circuit adapted to impress upon one of said cold electrodes frequency modulated carrier waves of a predeter-

mined center frequency, a second tunable circuit adapted to be resonated to said center frequency and connected to a second of said cold electrodes, means connected to each of said tunable circuits for providing substantial reduction of amplitude variation of the carrier waves, a tunable oscillator tank circuit operatively associated with the third cold electrode for applying thereto oscillatory voltage whose frequency differs from the aforesaid center frequency by a predetermined intermediate frequency, an output circuit coupled to said output electrode and tuned to said intermediate frequency, the carrier voltages on said first and second cold electrodes being in phase quadrature at the center frequency, and said amplitude modulated carrier waves whose center frequency is of said intermediate frequency being developed across said output circuit.

12. In combination with a tube provided with a cathode, an output electrode and at least three cold electrodes arranged in the electron stream between the cathode and output electrode, a source of angular velocity modulated carrier waves coupled to one of said cold electrodes, said source supplying waves of a predetermined center frequency located in a range of 42 to 50 megacycles, means applying to a second of the cold electrodes angular velocity modulated carrier waves of the aforesaid center frequency, the waves at said first and second cold electrodes being in substantial phase quadrature, means for applying to the third of said cold electrodes local oscillations having a frequency differing from said center frequency by an intermediate frequency of the order of 2 to 8 megacycles, and an output circuit connected to said output electrode and tuned to said intermediate frequency, said output circuit developing amplitude modulated waves of said intermediate frequency.

13. A method of receiving angular velocity-modulated carrier waves of a predetermined center frequency which comprises combining said waves with constant frequency local oscillations of a different frequency to produce modulated carrier waves of a lower center frequency, and simultaneously beating with said constant frequency oscillations additional angular velocity-modulated waves of said center frequency but in substantial phase quadrature with the original modulated carrier waves whereby the lower center frequency carrier waves are amplitude modulated.

14. In combination, means including spaced control elements of an electron discharge device for translating frequency modulated carrier waves to amplitude modulated carrier waves, means including an additional control element of said device for generating local oscillations of a different frequency from the center frequency of the said frequency modulated carrier waves, and means connected to the output of the translating device to develop said amplitude modulated carrier waves at a frequency equal to the difference between said center frequency and oscillation frequency.

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