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CONVERTER HARMONIC REDUCTION CIRCUIT

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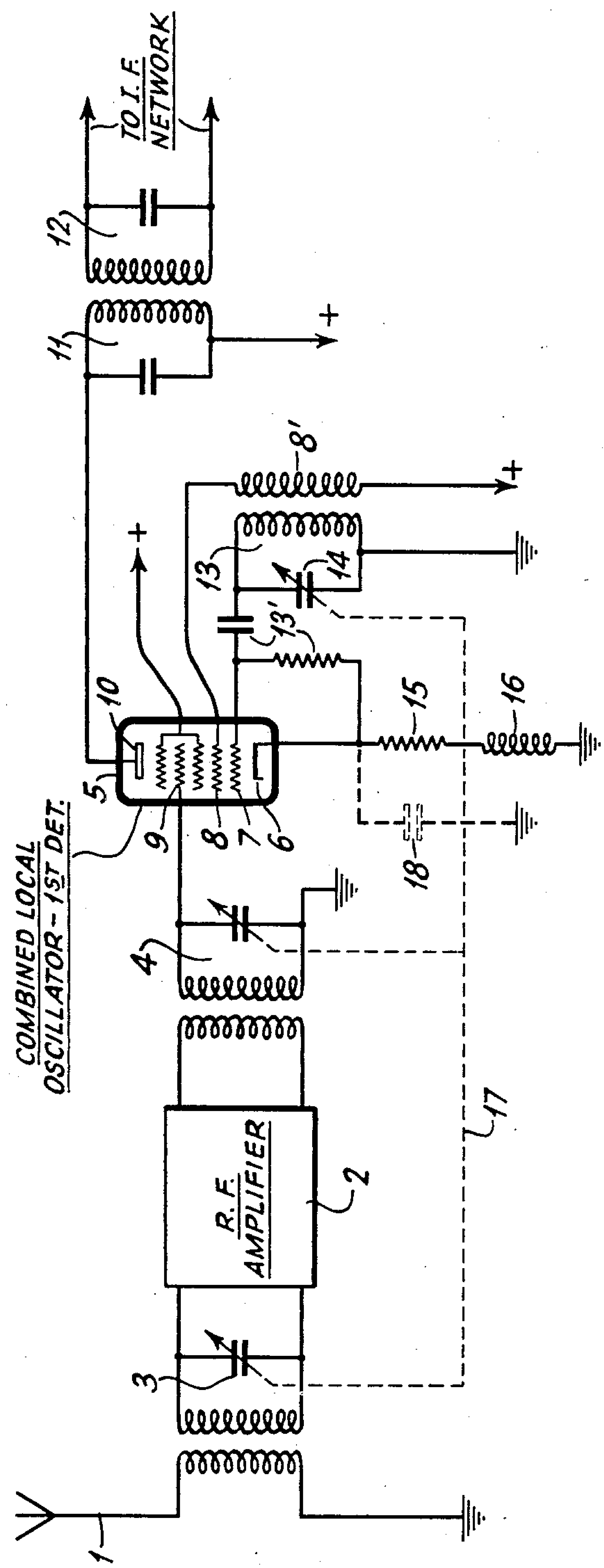

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CONVERTER HARMONIC REDUCTION CIRCUIT

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9 Claims. (Cl. 250—20)

My present invention relates to signal converter networks and more particularly to converter networks having means to minimize the production of spurious responses.

It has been well known that a signal converter network, whether of the combined local oscillator-first detector type or of the type employing an independent local oscillator, produces spurious responses by virtue of the non-linearity of the converter tube characteristic. Such spurious responses evidence themselves in the form of multiple reception of a signal along the tuning range; particularly it is found annoying to produce a whistle during reception of a signal carrier of twice the operating intermediate frequency value. Various attempts have been made in the past to minimize such spurious responses, generally caused by harmonics, but these have all involved additional circuit elements which increase the cost of production of a receiving system.

Accordingly, it may be stated that it is one of the main objects of my present invention to reduce the effects of the non-linearity of a converter tube characteristic by utilizing degenerative feedback at the signal and local oscillation frequencies.

Another important object of my present invention is to provide a signal converter network which has disposed in the cathode circuit thereof a resistor and inductance for developing signal and local oscillation voltages which are re-impressed upon the signal and oscillator grids in degenerative phase whereby predetermined uniform degeneration is secured.

Another object of my invention is to provide a converter network of the type utilizing a tube having signal and oscillation grids disposed in a common electron stream; the cathode circuit of the tube including an impedance network for developing voltages at signal and local oscillator frequencies, and the voltages being impressed in degenerative phase upon the aforesaid signal and oscillation grids, thereby to reduce the effect of the non-linearity of the converter tube characteristic.

Still other objects of my invention are to improve generally the efficiency and reliability of signal converter networks, and more especially to provide a converter network of the electron-coupled type which is not only free of spurious responses, but is economically manufactured and assembled in a radio receiver.

The novel features which I believe to be characteristic of my invention are set forth in particularity in the appended claims; the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description taken in connection with the drawing in which I have indicated diagrammatically a circuit organization whereby my invention may be carried into effect.

Referring now to the accompanying drawing, there is shown a superheterodyne receiver of a generally known type; the receiver comprising a signal collector 1 which may be, for example, the usual antenna circuit, although the collector may be a radio frequency distribution line, a loop antenna or the type of collector employed on a mobile structure such as an automobile. One or more stages of tunable radio frequency amplification, designated by numeral 2, may be utilized to amplify the signals collected at 1. The numeral 3 denotes the variable tuning condensers usually employed to tune the amplifier circuits 2. It is assumed that the signals may be collected in the broadcast band of 500 to 1500 kc., or that the short-wave bands are being tuned through. The amplified modulated carrier energy is impressed upon the tunable input circuit 4 of the converter tube 5.

The converter tube may be of the pentagrid type, and a 6A7 tube may be used for this purpose if desired. As is well known, such a tube usually comprises a cathode 6, an oscillator grid 7, an oscillator anode electrode 8, the signal grid 9 and an output electrode 10; the signal grid is usually shielded from the remaining electrodes by positive screening electrodes. The intermediate frequency (I. F.) energy is developed in the output circuit 11 which is tuned to the operating I. F. value. The latter may be chosen from a range of from 75 to 470 kc., and the numeral 12 denotes the I. F.-tuned input circuit of the following I. F. amplifier. As those skilled in the art well know, the amplified I. F. energy may be demodulated, and then the demodulated energy can be amplified at audio frequency, and finally reproduced in any desired type of loudspeaker. Furthermore, any well known type of automatic volume control circuit may be utilized to control the I. F. and radio frequency amplifiers.

The converter network shown in the drawing is specifically of the combined local oscillator-first detector type. That is to say, the oscillator anode 8 is connected to a source of positive direct current potential through a feedback coil 8′. The variable condenser 14 will vary the tuning of circuit 13 through a range of frequencies which differs from the signal frequency range of circuit 4, as well as the radio frequency amplifier circuits, by a value equal to the I. F. The tank circuit 13 is magnetically coupled to the coil 8'. The usual grid leak and condenser network 13' are employed in the oscillator grid circuit. The tank circuit 13 is in the grid lead to ground.

The cathode 6 of converter tube 5 is connected to ground through a path comprising resistor 15 and coil 16. The variable tuning condensers of the signal and local oscillator circuits can be unicontrolled as is indicated by the dotted line 17. Of course, a separate local oscillator tube can be employed, and in this case the local oscillations will be impressed upon the oscillator grid 7 in a manner well known to those skilled in the art. The latter are also fully aware of the fact that the converter network is of the electron-coupled type, and that the electron stream flowing from cathode 6 to the plate 10 is modulated at the signal and local oscillation frequencies. However, due to the non-linearity of the tube characteristic, spurious responses, in addition to the desired I. F. output, are caused, and particularly there is secured a whistle when tuning to a signal carrier in the region of twice the I. F. value. The aforesaid whistle is particularly noticeable when tuning in and out of a signal carrier frequency which is double the I. F. value. The production of this undesired whistle is caused by a beat between twice the frequency of the signal carrier when the signal carrier frequency is equal to double the I. F. value, and the local oscillation frequency.

According to the present invention, degenerative feedback both to the signal grid 9 and oscillator grid 7 is utilized to reduce the effects of the non-linearity of the characteristic of tube 5. Assuming that resistor 15 is the only element connected between cathode 6 and ground, it will be appreciated that since it is un-by-passed there will be developed thereacross voltage at signal carrier frequency as well as voltage at the local oscillation frequency. Since both the signal grid 9 and the oscillator grid 7 are connected to ground, the voltages developed at the two frequencies across resistor 15 will be impressed in degenerative phase on the grids 9 and 7. It can be demonstrated that the non-linearity of the tube characteristic is greatly reduced by virtue of this degenerative feedback, and hence the production of the second and higher harmonics will be greatly minimized. The whistle formerly produced at a signal carrier frequency of double the I. F. value is practically eliminated.

When using the resistor 15 by itself in the cathode lead it is found that the cathode to ground inherent capacity 18, shown in dotted lines, changes the magnitude of degenerative feedback with frequency. The effect of the inherent capacity 18 is substantially to decrease degenerative feedback of the signal and local oscillator voltages as the signal frequency is increased. It is important that all frequencies be degenerated at least up to a signal frequency value equal to four times the I. F. Hence, by inserting the coil 16 in series between resistor 15 and ground it is found that uniform degenerative feedback is secured over the entire signal frequency range up to a signal carrier frequency of four times the I. F. Generally, it can be stated that if the reactance of the inherent capacity 18 is equal to the magnitude of resistance 15 at a frequency four times the I. F. value, then the reactance of coil 16 should have a magnitude equal to one-half the magnitude of resistor 15 at a frequency equal to four times the I. F. value. That is to say, the impedance of the network 15—16—18 is substantially constant up to the limiting frequency.

In a signal converter having two frequencies impressed thereon, namely signal frequency energy and oscillator frequency energy, the desired output is the intermediate frequency which is the difference frequency between signal and oscillator frequencies. In addition to this desired output there appear other combination frequencies of harmonics of signal and oscillator frequencies. Of these the most annoying is that due to twice the signal frequency minus the oscillator frequency. When the signal frequency has a value equal to twice the intermediate frequency it can be seen that the resultant spurious frequency is the same as the desired intermediate frequency, and so will beat therewith in the second detector and produce an audio frequency. As the receiver is tuned this beat frequency will vary, producing a whistle. It is, therefore, seen that the spurious output frequency is due to non-linearity of the converter characteristic. This most annoying spurious response, namely that caused by the difference between twice the signal frequency and the oscillator frequency is due to the term in the converter characteristic next higher in order than the term producing the desired output. In the case of the electron modulator type converter where the desired output is due to the first order term of the characteristic the second order term results in this aforesaid spurious output. In the case of the square law modulator, where signal and oscillator voltages are applied to the same electrode, the desired output is due to the second order term and the spurious output described above is due to the third order term.

Now, if energy is fed back from the output to the input in degenerative phase, so as to oppose the primary impressed energy, the undesired or distortion terms are fed back likewise, provided the feedback impedance is such that it has the same magnitude for all of the frequencies entering into the conversion, both desired and spurious. Now this feedback of spurious or distortion frequencies is in the proper phase to oppose the distortion frequencies generated within the tube due to non-linearity of its characteristics, when the phase of the feedback primary frequencies is degenerative. The degeneration reduces the desired frequency output, but reduces the distortion frequencies so that they are a smaller percentage of the desired frequency terms. To a first approximation, the distortion percentage is reduced to the same degree as the desired conversion frequencies; that is, if the conversion is halved by degenerative feedback the percentage of distortion relative to the desired output is halved. This result is well known in inverse feedback amplifiers. In the case of signal converters it is necessary to feed back several frequencies, and to reduce distortion these must all be fed back in the same proportion. A resistance in the cathode circuit will present the same impedance to all frequencies, but in practice there is inherent capacity shunting a resistor in the cathode circuit due to stray capacities of cathode, wiring, etc. These capacities result in a lower feedback impedance for higher frequencies so that they are not all fed back in the proportion necessary to cancel distortion.

By adding an inductance in series with this capacity the feedback impedance is made uniform for a wide range of frequencies. It is well known from circuit theory that if the resistor be made equal to the capacity reactance at any given frequency, and the inductive reactance be made equal to half the resistance at that same frequency, the impedance of the combination is substantially uniform for all frequencies up to that given frequency. If that upper frequency be made at least as high as four times the intermediate frequency all frequencies up to that value, which is likewise the frequency of the second harmonic of the signal when the signal has a value twice the intermediate frequency, will be equally fed back and the desired reduction of spurious or distortion terms take place. This degeneration, in addition to reducing the magnitude of distortion, has other beneficial effects. Since it provides feedback at oscillator frequency it decreases the effect of the oscillator tube on the oscillatory circuit thus stabilizing the oscillator frequency against changes due to variation of voltage; it decreases the noise generated in the converter; and increases the output impedance to intermediate frequencies thus improving the selectivity.

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

What I claim is:

1. In a converter of the type including a tube having local oscillation and signal input electrodes spaced apart in a common electron stream to an output electrode, the method comprising impressing signal and local oscillation voltages on said respective electrodes, deriving voltages from said stream at the signal and local oscillation frequencies, and impressing said derived voltages in degenerative phase upon said respective electrodes thereby to reduce the effect of the non-linearity of the tube characteristic.

2. In a converter which is provided with at least two spaced electrodes disposed in an electron stream to a common output electrode, the method which includes impressing signals on one of said two electrodes and local oscillations upon the second electrode, deriving from the electron stream a voltage of signal frequency, impressing the last voltage upon the said one electrode in degenerative phase, deriving a second voltage from the electron stream of local oscillation frequency, and impressing the second voltage upon the said second electrode in degenerative phase.

3. In a converter network of the type using a tube provided with at least two grids spaced successively in an electron stream to an output plate, the method which includes varying the voltages of said two grids at two different frequencies thereby to produce in the said output plate a difference frequency current, and simultaneously varying the voltages of said grids at the said different frequencies but in degenerative phase thereto to minimize the production of harmonics.

4. In a converter network, a tube having a cathode, a plate, and at least two grids spaced apart in the electron stream from the cathode to plate, a source of signals coupled to one grid, a source of local oscillations of a different frequency coupled to the second grid, an impedance network connected to the cathode and being traversed by the said electron stream thereby developing voltages at signal and said different frequencies, and means impressing said last voltages upon the respective grids in degenerative phase.

5. In a converter network, a tube having a cathode, a plate, and at least two grids spaced apart in the electron stream from the cathode to plate, a source of signals coupled to one grid, a source of local oscillations of a different frequency coupled to the second grid, an impedance network connected to the cathode and being transversed by the said electron stream thereby developing voltages at signal and said different frequencies, and means impressing said last voltages upon the respective grids in degenerative phase, said impedance network comprising a resistor in series with an inductance.

6. In a converter network, a tube having a cathode, a plate, and at least two grids spaced apart in the electron stream from the cathode to plate, a source of signals coupled to one grid, a source of local oscillations of a different frequency coupled to the second grid, an impedance network connected to the cathode and being transversed by the said electron stream thereby developing voltages at signal and said different frequencies, and means impressing said last voltages upon the respective grids in degenerative phase, said impedance network being constructed to provide substantially uniform degeneration up to a signal frequency equal to four times the value of the difference frequency of said signal and oscillation frequencies.

7. In a signal reception system, a frequency converter network comprising a tube provided with a cathode, an output electrode and at least two control electrodes disposed in the electron stream between the cathode and output electrode, means for varying the voltage of one control electrode at a desired signal frequency of a signal frequency range, means for varying the voltage of the second control electrode at an oscillation frequency of an oscillation frequency range, a resonant circuit coupled to said output electrode and tuned to an intermediate frequency, an impedance in the space current path of the tube for developing voltages of said signal and oscillation frequencies, and means for impressing said last named signal frequency and oscillation frequency voltages on said signal and oscillation electrodes respectively in degenerative phase.

8. In a signal reception system, a frequency converter network comprising a tube provided with a cathode, an output electrode and at least two control electrodes disposed in the electron stream between the cathode and output electrode, means for varying the voltage of one control electrode at a desired signal frequency of a signal frequency range, means for varying the voltage of the second control electrode at an oscillation frequency of an oscillation frequency range, a resonant circuit coupled to said output electrode and tuned to an intermediate frequency, an impedance in the space current path of the tube for developing voltages of said signal and oscillation frequencies, and means for impressing said last named signal frequency and oscillation frequency voltages on said signal and oscillation electrodes respectively in degenerative phase, the constants of said impedance being so chosen that said degenerative voltages are substantially uniform over said signal frequency range up to a signal frequency value equal to four times said intermediate frequency value.

9. In a signal reception system, a frequency converter network comprising a tube provided with a cathode, an output electrode and at least

two control electrodes disposed in the electron stream between the cathode and output electrode, means for varying the voltage of one control electrode at a desired signal frequency of a signal frequency range, means for varying the voltage of the second control electrode at an oscillation frequency of an oscillation frequency range, a resonant circuit coupled to said output electrode and tuned to an intermediate frequency, an impedance in the space current path of the tube for developing voltages of said signal and oscillation frequencies, and means for impressing said last named signal frequency and oscillation frequency voltages on said signal and oscillation electrodes respectively in degenerative phase, said impedance comprising an unbypassed resistor arranged in series with an inductance.

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