

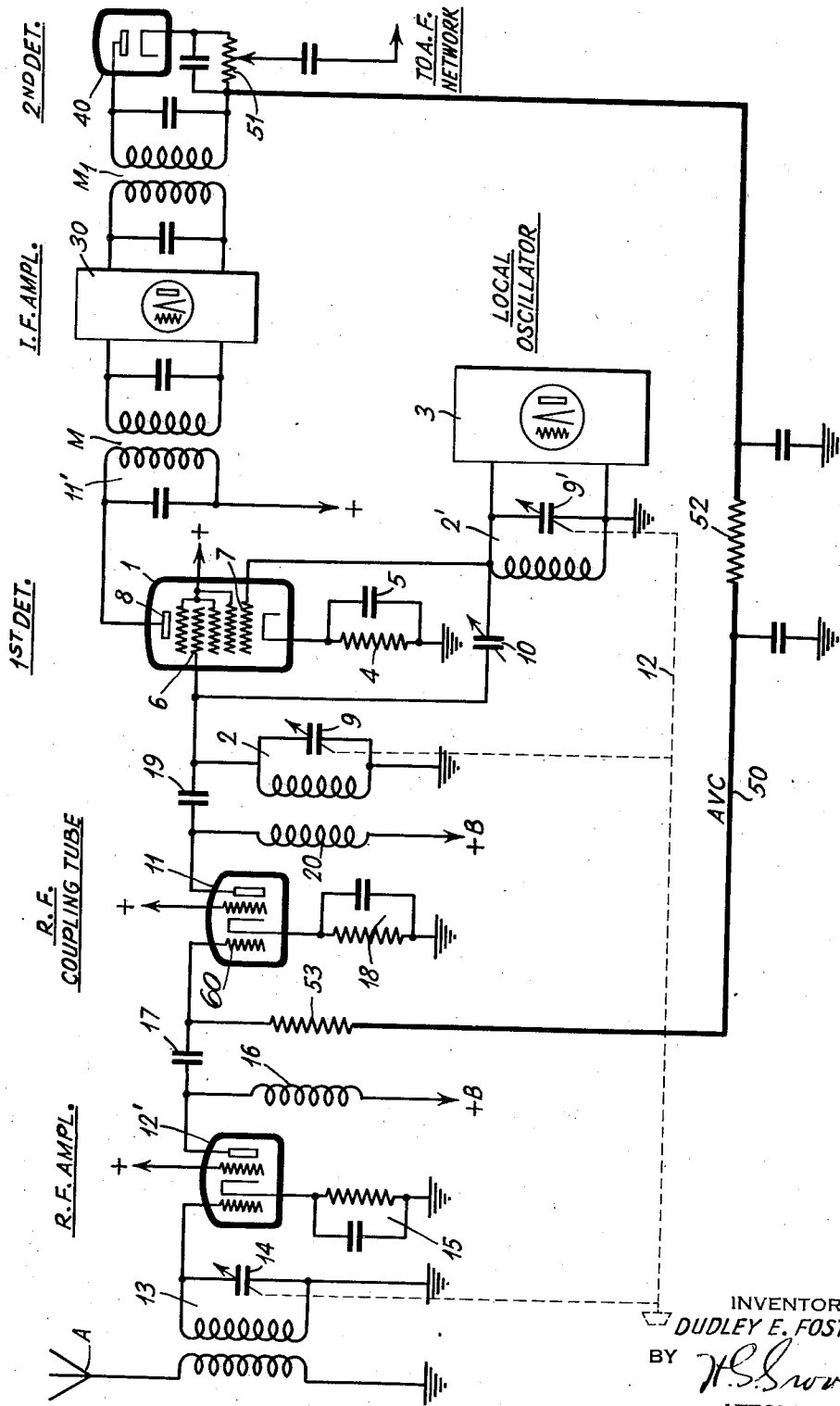
April 9, 1940.

D. E. FOSTER

2,196,259

SUPERHETERODYNE RECEIVER

Filed July 1, 1937



INVENTOR
DUDLEY E. FOSTER
BY *H. S. Swer*
ATTORNEY

UNITED STATES PATENT OFFICE

2,196,259

SUPERHETERODYNE RECEIVER

Dudley E. Foster, South Orange, N. J., assignor to
Radio Corporation of America, a corporation
of Delaware

Application July 1, 1937, Serial No. 151,353

5 Claims. (Cl. 250—20)

My present invention relates to radio frequency signal converter circuits, and more particularly to converters of the electron coupled type.

As is well known, the frequency converter tube, or first detector, of a superheterodyne receiver produces in its output circuit the sum and difference frequencies of the signal and locally produced oscillation frequencies. In addition to these sum and difference frequencies, there are produced frequencies equal to the sum and difference of integral multiples of the signal and oscillator frequencies. These latter frequencies are usually referred to as higher order effects, since they are due to terms, in the expression representing the tube characteristic, higher in order than the term which results in the desired operating intermediate frequency; for example, in the simple type of converter tube, wherein the signal and oscillator voltages are simultaneously applied to a common control grid, if the characteristic of the plate current be expressed as a power series, i. e., a series whose successive terms are ascending powers of the grid voltage, then the second order (voltage squared) term results in the desired conversion frequency and higher orders result in undesired frequency terms.

The electron coupled type of frequency converter, and its many circuit forms, is well known at the present time. In such a converter the oscillator voltage is applied to one control grid while the signal voltage is applied to another grid, the latter being usually spaced from the former and both grids being disposed in the electron stream flowing between the cathode and output electrode of the tube. In this type of converter the higher order terms give undesired frequencies, just as in the simple type of converter tube. Only those frequencies falling within the response band of the intermediate frequency network will be transmitted to the second detector, or demodulator. However, any undesired term falling within the intermediate frequency network response band will likewise reach the demodulator, and thus give an undesired response. This difficulty is most commonly encountered when twice the intermediate frequency falls within the signal frequency range it is desired to receive. In this case the intermediate frequency can result not only from the difference between the signal and oscillator frequencies, but, also, from the difference between twice the signal frequency and the oscillator frequency.

The latter problem can be more clearly understood when viewed in the light of an actual ex-

ample. Assuming that the operating I. F. is 500 K. C., then the oscillator frequency will be 1500 K. C. when the receiver is tuned for reception of a 1000 K. C. signal. If, now, the oscillator frequency be slightly changed to 1501 K. C., then the resultant I. F. from the first order term will be 501 K. C. The second order term will give a frequency equal to twice the signal frequency, i. e., the difference between 2000 K. C. and 1501 K. C., or 499 K. C. It will, thus, be seen that there will be applied to the second detector two frequencies of 501 K. C. and 499 K. C., with the result that a beat note equal to their difference, 2 K. C., will be heard.

At signal frequencies other than twice the I. F., multiple response will be evidenced instead of audible whistles. Consider again, a superheterodyne receiver using a 500 K. C. I. F. with an input signal of 1020 K. C. If the oscillator frequency is 1520 K. C., then the I. F. of 500 K. C. will be obtained. Furthermore, if the oscillator frequency is 1540 K. C., the second order term of the signal grid characteristic will give an output of twice signal frequency minus oscillator frequency, or 2040 K. C., minus 1540 K. C., resulting in 500 K. C. It is seen, therefore, that for any applied signal frequency, there are at least two oscillator frequencies which will result in the correct I. F.

In my application Serial No. 73,998, filed April 13, 1936, there have been disclosed, and claimed, arrangements functioning substantially to reduce undesired responses in a converter of the electron coupled type, which responses correspond to terms higher than the first order term in the expression representing the converter tube characteristic; the reduction in undesired responses being accomplished by applying the local oscillator voltage simultaneously to the signal and oscillator grids, but the oscillator voltage being impressed on the two grids in out-of-phase relation, and the magnitude of the out-of-phase oscillator voltage being chosen to secure the substantial reduction of the higher order terms referred to.

In existing electron discharge tubes of the type employed in electron coupled converters, the amount of local oscillator voltage to be applied to the signal grid for cancellation of undesired responses is a function of the bias on the signal grid, since the tube characteristic with respect to the signal grid is not purely exponential. In the aforesaid application, therefore, an arrangement was shown wherein local oscillator voltage of an electron coupled converter was applied to the

signal and oscillator grids in phase and magnitude relations substantially to reduce the higher order effects resulting in undesired responses in the frequency range it is desired to receive, automatic volume control action being employed on the converter; this dual result being secured by utilizing a phase inverter tube to impress local oscillator voltage on the signal grid, and the bias of the inverter tube being varied concurrently with that of the signal grid of the signal converter tube with the result that the proper amount of local oscillator voltage was applied to the signal grid for any value of signal grid bias. Another arrangement shown was an electron coupled converter tube which not only had applied to its signal grid a local oscillator voltage in phase and magnitude substantially to eliminate the undesired responses due to the higher order effects, but wherein the direct current voltage of the oscillator and signal grids were varied in dependence upon received signal amplitude variation.

However, in many instances of receiver operation it is of distinct disadvantage to apply the AVC bias to the converter tube. In such cases the prior arrangements of my aforesaid application would not be sufficiently effective. In the ideal condition the converter network should embody the harmonic cancellation of my aforesaid application and yet be subject to AVC action; the AVC, however, being such as to avoid spurious responses in the converter network.

It may be stated to be one of the important objects of my present invention to provide a converter network of the type employing reverse oscillator voltage on the signal grid for harmonic cancellation; and AVC action being employed by automatically varying the gain of a radio frequency coupling tube disposed between the signal source and the converter input circuit.

Another important object of the invention is to provide in a superheterodyne receiver, a converter tube whose input circuit is coupled to a tuned radio frequency amplifier through an untuned amplifier; AVC bias being applied to the coupling tube to control the intermediate frequency output of the converter.

Another object of my invention is to provide a superheterodyne receiver with relatively poor selectivity preceding the converter tube and high selectivity prior to the AVC bias source; the AVC bias being applied to an untuned coupling tube feeding the converter, and the normal bias on the latter being high whereby spurious responses in the converter are not developed when the AVC bias becomes small.

Yet another object of my invention is to provide an AVC arrangement for a receiver, wherein the AVC bias is applied to an untuned radio frequency amplifier which functions only to couple successive tuned radio frequency circuits of the 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 circuit employing the present invention. The numeral 1 designates a pentagrid converter tube which is

well known to those skilled in the art, and which may be of the 6L7 or 6A8 type. The input electrodes of the tube are connected across a tunable signal input circuit 2, the latter circuit being coupled to a source of modulated radio frequency signal energy. The local oscillator network is schematically represented by the numeral 3, and is connected between the first grid 7 and the grounded side of the cathode bias resistor 4, the latter being shunted by the usual by-pass condenser 5. The fourth grid 6 is connected to the high alternating potential side of the input circuit 2, and the signal grid 6 and oscillator grid 7 have disposed between them a pair of positively biased grids. A positively biased grid is, also, disposed between the output plate electrode 8 and the signal grid 6.

The numeral 9 denotes the usual variable tuning condenser disposed in the input circuit 2, and the condenser 9 is to be understood as being adjustable over a relatively wide frequency range, as, for example, the broadcast range of 500 to 1500 K. C. Of course, the tuning range of circuit 2 may be in the higher frequencies, and it is to be clearly understood that the local oscillator circuit 3 is simultaneously tunable, by means of its own tuning element, over a frequency range which differs from the signal frequency range by the operating I. F. The I. F. network is disposed in the circuit connected to the plate 8.

It is not believed necessary to go into the details of the functioning of the converter tube 1. Those skilled in the art are fully aware of the fact that there is produced in the circuit connected to the output electrode 8, the sum and difference frequencies between the applied signal frequency and the local oscillator frequency, as well as frequencies equal to the sum and difference of integral multiples of the signal and oscillator frequencies. The electron stream flowing between the cathode and plate 8 is modulated at the frequencies of the signal and oscillator voltages, and the various modulation frequencies, as explained above, are produced in the circuit connected to the plate 8. The I. F. network being resonated to the desired operating I. F., only those frequencies falling within the response band of the I. F. network will be transmitted to the demodulator.

However, undesired responses produced by the second, third or higher order effects will likewise reach the demodulator, and give undesired responses if any undesired term falls within the I. F. network response band. To reduce substantially these undesired responses there is impressed upon the signal grid 6 a portion of the locally produced oscillator voltage, and this impression is made through an impedance. The impedance is designed to provide the proper phase so as to produce reduction of the higher order effects.

The impedance may be inductive or capacitive. The impedance must be chosen of such phase and magnitude as to cancel out the response due to the second order term. If the third, or higher, order effect results in undesired responses in the desired frequency range, then the amount of out-of-phase oscillator voltage applied to the signal grid 6, through the impedance, is adjusted to cancel higher order responses.

In the drawing there is shown a converter network wherein the out-of-phase oscillator voltage is applied to the signal grid 6 of the converter tube 1 through condenser 10. The latter is made adjustable so that it can be varied in magnitude to the point where the undesired responses in

I. F. network 11 can be cancelled. The condenser 19 is connected between the grid 6 and the high alternating potential side of the tunable oscillation circuit 2' of the local oscillator. The dotted line 12 denotes the usual mechanical coupling between the rotors of the variable tuner condensers 9 and 9'.

It is to be clearly understood that any of the arrangements shown in my aforesaid application can be used to impress the reverse oscillator voltage on the converter signal-grid. When the AVC action is applied to the converter tube the second harmonic cancellation is affected. This arises by virtue of the fact that the signal grid characteristic is not purely exponential in existing tubes. The amount of oscillator voltage to be applied to the signal grid for harmonic cancellation is a function of the bias on the signal grid. Since the signal grid bias varies in magnitude when AVC is used, it follows that the harmonic cancellation voltage will also vary. In my earlier application there was used a device for insuring the application of the proper amount of oscillator voltage for any signal grid bias. Since harmonic cancellation can be made very effective with fixed bias on the converter signal grid, in my present arrangement no AVC bias is applied to the latter. Instead, the AVC bias is applied to an untuned amplifier 11 which functions as a coupling tube between the radio frequency amplifier 12' and the converter tube 1. The amplifier 12' has a tunable input circuit 13 provided with a variable condenser 14; the rotor of the latter being arranged for adjustment by the unicontrol mechanism 12. The antenna A is coupled to the input circuit 13; the latter is tunable over the same signal frequency range as the converter circuit 2. The usual resistor-condenser network 15, disposed in the grounded cathode lead of amplifier 12', provides normal bias for the signal grid. The amplifier plate is connected to a source of positive potential through an inductance coil 16, and the latter may have a magnitude of approximately 20 to 2,000 microhenries. The plate side of coil 16 is connected to the grid of coupling tube 11 through a condenser 17 which has a low impedance to radio frequency currents. The bias network 13 provides the necessary initial bias for maximum gain of tube 11. The plate of the coupling tube is connected to the high alternating potential side of circuit 2 through a condenser 19; the latter may be of the same magnitude as condenser 17. The coil 20 connects the coupling tube plate to a source of positive voltage. It will be understood that the coupling tube network is untuned, and functions solely to transfer selected signal energy, amplified in amplifier 12', to the signal input circuit 2 of the converter.

The I. F. energy in the I. F. output circuit 11 may be amplified in one, or more, tuned I. F. amplifiers 30. The reference characters M and M₁ denote tuned coupling transformers which provide considerable selectivity for the I. F. network. The second detector 40, which may be of the diode type, has the amplified I. F. energy impressed thereon. The audio component of the detected I. F. energy is impressed upon an audio utilization network which may comprise one, or more, audio amplifiers followed by any desired type of reproducer. The direct current voltage component of detected I. F. energy is used for the AVC function. For this purpose the AVC lead 50 is connected to a point of negative potential on the diode load resistor 51. The AVC

lead includes the usual time constant network 52, and a filter resistor 53. It is to be understood that AVC bias is impressed on the control grid 60 of the coupling tube 11, the magnitude of the bias being dependent upon the magnitude of the signal carrier amplitude.

AVC bias may, also, be applied through lead 50 to the radio frequency amplifier 12', and to the I. F. amplifiers. However, the AVC bias is not applied to the converter tube; the coupling tube is automatically varied in gain in order to supply the AVC action which would otherwise be supplied by the converter tube. As the signal amplitude increases, the AVC bias applied to the control grid of coupling tube 11 increases. This results in a decrease in the gain of tube 11, and there is a decreased signal transfer from the amplifier 12' to the converter signal input circuit 2. In this way harmonic cancellation is secured in the converter tube by impressing the reverse oscillator voltage on the signal grid 6, and yet the benefit of AVC action is secured without affecting the magnitude of the reverse oscillator voltage.

The magnitude of the bias resistor 4, disposed in the cathode circuit of the converter tube, is so chosen that a relatively high bias is normally provided for the signal grid 6. This bias may be of the order of -6 volts. The advantage of operating the converter tube at a relatively high bias is readily appreciated when it is realized that there is comparatively poor radio frequency selectivity preceding the converter input circuit 2. If a low bias were used on the converter tube, and the AVC bias vanished or appreciably decreased by virtue of a certain degree of detuning from a desired signal, spurious or "saw tooth" responses would occur in the output of the converter. This is due to the fact that the AVC source is preceded by a high degree of selectivity, and with a small degree of detuning there might still be sufficient signal energy to swing the converter signal grid positive, the AVC bias being greatly decreased in such a case. If the signal grid of the converter tube swings positive a large number of harmonics of the signal frequency is generated; these harmonics then beat with the harmonics of the oscillator frequency resulting in a series of spurious responses on each side of the desired signal. With my circuit "saw tooth" responses will not occur in the converter network, since any overloading will occur on the coupling tube should the AVC bias disappear; it being noted that there is no oscillator voltage impressed on the coupling tube and therefore the possibility of spurious responses does not exist.

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 superheterodyne receiver, a first detector system comprising a tube having a cathode and an oscillation electrode near said cathode, means electrically associated with said oscillation electrode for varying the alternating current voltage thereof at a predetermined locally produced oscillation frequency, said tube including a control grid and an anode located in the space path beyond said oscillation electrode, a source of signal voltage, an untuned amplifier tube

coupling the source to said control grid and said cathode, additional means for impressing upon said control grid said locally produced oscillations in phase and magnitude such that undesired responses due to the second order term of the detection characteristic are substantially reduced, and means responsive to signal amplitude variation for automatically controlling the gain of said untuned amplifier.

2. In a superheterodyne receiver, a first detector system comprising a tube having a cathode and an oscillation electrode near said cathode, means electrically associated with said oscillation electrode for varying the alternating current voltage thereof at a predetermined locally produced oscillation frequency, said tube including a control grid and an anode located in the space path beyond said oscillation electrode, a source of signal voltage coupled between said control grid and said cathode through a coupling tube, additional means for impressing upon said control grid said locally produced oscillations in phase and magnitude such that undesired responses due to the second order term of the detection characteristic are substantially reduced, highly selective means for developing a bias control voltage which automatically varies with the intensity of said signal source, means for applying said bias voltage to said coupling tube, and means for providing a relatively high normal bias on said control grid.

3. In combination, a first detector network of a superheterodyne receiver, an electron discharge tube provided with at least a cathode, an output electrode, a pair of control electrodes disposed between the cathode and output electrode, and means electrostatically shielding said pair of control electrodes, a tuned signal input circuit connected between the cathode and one of the control electrodes, a signal source, an untuned amplifier tube coupling said source to the signal input circuit, means coupled to the cathode and the other control electrode for varying the alternating current voltage of said other control electrode at a frequency rate which differs from the signal frequency by a predetermined intermediate frequency, means for impressing on said first control electrode alternating current voltage varying in frequency at said oscillation

frequency rate, the phase of the alternating current voltage impressed on said first control electrode being related to the phase of the voltage on said other control electrode substantially to reduce the effect of the second order term of the detection characteristic on the electron stream flowing between the cathode and said output electrode, and automatic volume control means for controlling the untuned amplifier gain.

4. In a first detector network of a superheterodyne receiver, an electron discharge tube which includes a cathode, an anode and at least two control grids disposed in the electron stream between the cathode and anode, a resonant network in the anode circuit which is tuned to an operating intermediate frequency, a tunable signal input circuit connected between the cathode and one of the control grids, a source of signals, a tube coupling the source to said tunable input circuit, a source of local oscillations, variable over a predetermined local oscillator frequency range, coupled between the cathode and the other control grid, means, electrically associated with said local oscillation source and the said signal input circuit, for impressing upon said first control grid local oscillator voltage which is out-of-phase with the oscillator voltage impressed on the other control grid, and means, responsive to variations in signal amplitude, for automatically regulating the gain of the coupling tube.

5. In combination with a converter tube having a signal input circuit, a local oscillator network, and a highly selective intermediate frequency output circuit, said converter tube including means to bias it to a relatively high bias value in the absence of signals, a signal selector circuit of relatively low selectivity, an untuned amplifier coupling the selector circuit to the converter input circuit, and automatic volume control means responsive to the signal intensity at the output of the highly selective output circuit for varying the untuned amplifier gain said bias value being sufficiently high to prevent spurious responses in said intermediate output circuit upon said signal intensity decreasing to a relatively low value.

DUDLEY E. FOSTER.