Aug. 18, 1936. W. VAN B. ROBERTS 2,051,178

COMBINED OSCILLATOR DETECTOR CIRCUIT

Filed May 25, 1934

Fig. 1

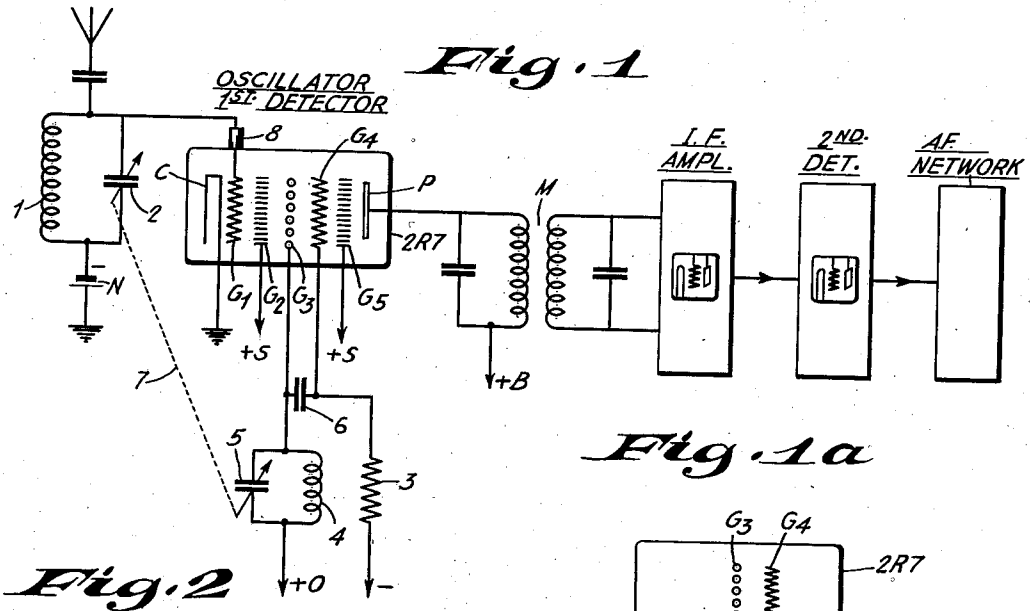


Fig. 1a

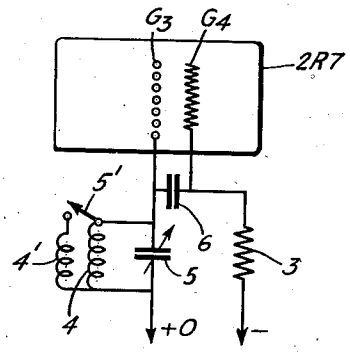


Fig. 2

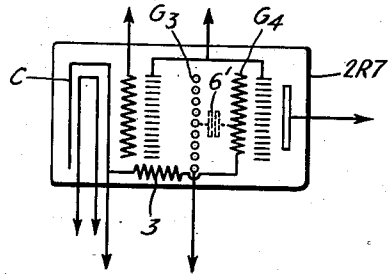
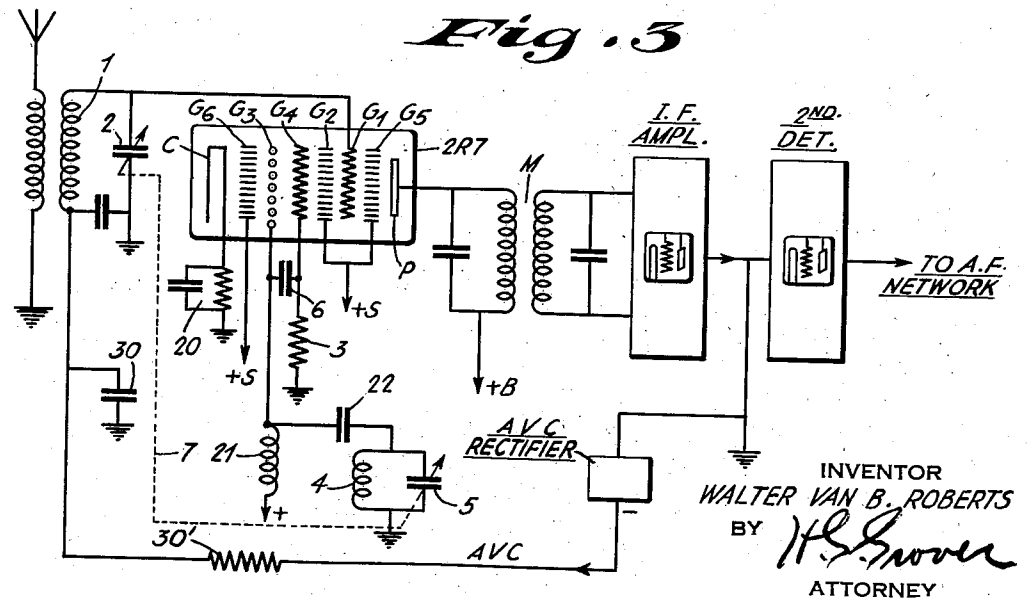


Fig. 3



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COMBINED OSCILLATOR-DETECTOR CIRCUIT

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6 Claims. (Cl. 250—20)

My present invention relates to frequency changing circuits, and more particularly to combined local oscillator-first detector circuits adapted to receive radio signals.

Combined oscillator-detector circuits, or converter circuits, are known in the prior art for superheterodyne receivers. In such converter circuits it is customary to employ a tickler coil in the local oscillator portion of the converter network to secure the regenerative feedback of energy which provides the local oscillations. Such a tickler coil, when utilized in a multi-range receiving set, necessitates the use of a double switching connection between the local oscillator coils, which coils are used for the different ranges, and the particular oscillator electrodes to which the coils are connected.

It may be stated that it is one of the main objects of the present invention to provide a converter network, and particularly one of the electron coupled type, wherein simplified switching of the oscillator circuits for multi-range operation is secured by eliminating the use of a tickler coil, the oscillator electrode coupling being solely capacitative, and being provided by disposing the oscillator anode and oscillator control grid in the converter tube in such a manner that the two electrodes are in similar phase with respect to their alternating voltages when connected for oscillation generation.

It is another important object of this invention to provide a converter of the electron coupled type, the converter being characterized by the disposition of the oscillator anode electrode and the oscillator grid electrode in a region receiving an electron flow tending to be independent of the oscillator electrode potentials, the oscillator anode being disposed closer to the cathode than the oscillator grid, and the signal grid being disposed outside this region, the electrode construction creating a negative transconductance between the oscillator anode and the oscillator grid and thereby permitting oscillations to be produced by merely providing a capacity connection between the two oscillator electrodes to maintain them in similar phase with respect to their radio frequency components of potential.

Another object of the invention is to provide a converter of the electron coupled type wherein the oscillator electrodes are so geometrically related to each other and the remaining electrodes of the tube that a negative transconductance is created between the oscillator electrodes, the signal grid being surrounded by a screen of positive potential disposed between the plate and the oscillator grid thereby permitting the use of automatic volume control bias potential on the signal grid to vary the conversion gain of the converter tube without reducing the strength of the locally produced oscillations.

Still other objects of the present invention are to improve combined oscillator-first detector circuits of present superheterodyne receivers, and more specifically to provide such converter circuits which are not only reliable in operation, but economically constructed and assembled in radio receivers.

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, both as to 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 diagrammatically shows a superheterodyne receiver embodying the invention,

Fig. 1A shows a fragmentary portion of the system shown in Fig. 1, embodying a wave range switching device,

Fig. 2 shows a modified form of converter tube,

Fig. 3 shows still another modification of the invention.

Referring now to the accompanying drawing, wherein like reference characters in the different figures represent similar circuit elements, there is shown in Fig. 1 a superheterodyne receiver of conventional construction, except for the converter network. This receiver embodies the usual intermediate frequency amplifier preceded by a combined local oscillator-first detector circuit, and followed by a second detector. The output of the second detector is impressed upon an audio amplifier network, and the latter may comprise one, or more, stages of audio amplification and/or a reproducer of any well known type. The signal input circuit of the converter tube 2R7 comprises a tunable signal circuit including coil 1 and variable tuning condenser 2, the high alternating voltage side of the input circuit being connected to a signal collector, such as an antenna circuit. The low alternating voltage side of the input circuit is connected to ground through a source of negative grid biasing voltage N. The signal output circuit of the converter tube comprises the usual intermediate fre-

quency coupling transformer M having its primary and secondary windings tuned to the operating intermediate frequency. Since these various networks of a superheterodyne receiver are well known to those skilled in the art, the specific construction of the tube 2R7, and its associated circuits, will now be described in detail.

The converter tube comprises a cathode C of the indirectly heated type, whose potential will be taken as the reference point and indicated by the ground symbol. The plate of the tube is designated by the reference character P, and this plate is connected to the high alternating voltage side of the primary circuit of transformer M. The plate P is connected to the positive terminal of a voltage source B, the latter not being shown to preserve simplicity of disclosure. Between the cathode C and the plate P are disposed five cold electrodes G_1 to G_5 inclusive. Between the electrode G_2 and the cathode there is disposed the signal grid G_1, and the signal grid is connected to the high alternating voltage side of the tunable signal input circuit.

The reference character G_3 denotes the local oscillator anode electrode, while the reference character G_4 denotes the local oscillator grid which is disposed between the electrode G_3 and the positive screen electrode G_5. It will be noted that each of the grids G_1 and G_4 is represented by a zigzag line; the positive screen electrodes are denoted by short parallel lines and the oscillator anode G_3 is denoted by a line of small circles. These symbolic reprepresentations are employed throughout the remainder of the drawing to denote these various electrodes. The screen electrodes G_2 and G_5 are connected to sources of positive voltage S, while the oscillator grid G_4 is connected to a source of negative voltage through a leak resistor 3. The oscillator anode G_3 is connected to a source of positive voltage O through the tunable oscillator circuit which includes the coil 4 and the variable tuning condenser 5. A condenser 6 of preferably large capacity is connected between the oscillator grid G_4 and the oscillator anode G_3. The dotted line 7 denotes a mechanical uni-control arrangement connected between the rotors of the tuning condensers 2 and 3. It will be understood, of course, that the tunable signal circuit and the tunable local oscillator circuit differ from each other at all times by the operating intermediate frequency. Again, the input circuit 1, 2 need not be coupled to the antenna, but may be preceded by one, or more, stages of tunable radio frequency amplification.

The tube 2R7 is similar in principle to the 2A7 type tube, the pentagrid converter, in that the electrode G_2 is a screen electrode, on both sides of which control voltages act on the electron stream flowing to the plate P. However, the tube differs from the 2A7 type tube in that a local oscillator system is employed which is of the constant current type. The use of such an oscillator involves advantages which will be pointed out below.

The radio frequency potentials of electrodes G_3 and G_4 are of the same phase due to the coupling condenser 6, but the direct current potentials are not the same. A constant current, neglecting signal input, emerges from the screen electrode G_2, and divides between the electrode G_3 on the one hand and the combination G_5–P on the other hand. When G_4 is more negative, the flow of electrons to G_5–P is decreased, and hence the electrode G_3 takes up the extra current lost to the plate P and G_5. Since this constitutes a negative transconductance between G_4 and G_3, the local oscillator circuit is caused to oscillate by the feedback condenser 6. As far as the effect on the plate current goes, the resultant effect of electrodes G_3 and G_4 is the same as that of a single control grid between electrodes G_2 and G_5 supplied with local oscillator voltage. The electrode G_5, if desired, may be omitted, or it may be connected within the tube to the electrode G_2.

Its essential function is to provide a high output impedance for the plate P, and it is pointed out that this may, also, be accomplished by leaving a large spacing between electrodes G_4 and P. The voltages N, S, O and B may be derived from a single potentiometer connected across the usual power supply system. Instead of operating the oscillator grid G_4 from an external source of negative voltage through leak 3, it is also within the scope of the present invention to connect the oscillator grid to a self bias resistor in the cathode lead. This is, also, true in connection with the bias voltage N, since the usual grid biasing network may be disposed in the cathode lead to provide the negative voltage for signal grid G_1. The reference character 8 denotes the usual connector cap provided on the converter tube.

It will be observed that since the transconductance between the oscillator anode and grid is negative, a coupling condenser 6 is sufficient to provide the feedback for oscillation. It is not necessary to utilize a feedback coil to provide the proper regenerative phase relationship, as in the case of circuits known in the prior art of this type. Because of this present construction, only a single connection may be utilized between the oscillator anode G_3 and the tunable oscillator circuit. The value of this single connection advantage is in the case where the converter network is employed in an "all-wave" set.

In Fig. 1A there is shown a fragmentary portion of a multi-range set using the converter network in Fig. 1, only the electrodes G_3 and G_4 being shown. The numeral 4' designates a tuning coil arranged to be connected in shunt with the coil 4, a switch 5' being utilized to make the shunt connection. When the switch is open, then variation of the tuning condenser 5 will result in tuning the local oscillator through the broadcast range, or more generally the longer wave length range, of local oscillation frequencies. When the switch 5' is closed, the smaller tuning coil 4' is connected in shunt with coil 4, and variation of condenser 5 will then tune the local oscillator network through the shorter wave length range of local oscillation frequencies. It will be observed that to change from the long wave range to the short wave range it is only necessary to manipulate the single switch 5'. This is a distinct advantage over the prior art, wherein two connections would have to be changed, and this advantage is secured by virture of the construction of the tube 2R7.

The local oscillator circuit can readily be rearranged to allow grounding the tuning condensers. For example, the tuned circuit may be put between G_4 and ground (in place of leak 3) while a radio frequency choke is connected between G_3 and the source of positive potential in place of the tuned circuit. In general, the conditions necessary to produce oscillation are merely to connect G_3 and G_4 together as to radio frequency potentials, to provide a tuned (anti-resonant) circuit or its equivalent such as a crystal

between one of these electrodes and the cathode, and to maintain the direct potential of G_4 somewhat negative, and the direct potential of G_3 positive. In actual practice, the total number of prongs to be used for tube **2R7** may be reduced by utilizing the construction shown in Fig. 2, especially if high frequencies are to be generated.

It will be observed that in this construction the coupling condenser **6** of Fig. 1 is replaced by the inherent capacity **6'**, shown in dotted lines, between the oscillator anode G_3 and the oscillator grid G_4. The leak return **3** is disposed within the tube enevolope, and is connected to the cathode C. It will be observed that only seven prongs need be utilized in connection with the tube. Only a small capacity coupling is required because at very high frequencies it is sufficient, while at medium frequencies the high circuit impedances make a small coupling sufficient.

When it is desired to regulate the gain of the tube **2R7** in dependence upon the received signal amplitude, thus providing automatic volume control, it is only necessary to re-arrange the electrodes of the tube in the manner shown in Fig. 3. In this case the signal grid G_1 is disposed between the positive screen electrodes G_2 and G_5. The two screen electrodes may be connected together to a common source of positive voltage S. The oscillator anode G_3 is disposed between the oscillator grid G_4 and a positive cold electrode G_6, the latter being constructed in a manner similar to the other two positive screen electrodes. The electrode G_6 is disposed adjacent the cathode C. The three screen electrodes G_6, G_2 and G_5 may be connected to the same voltage source S, unless G_6 is located rather close to the cathode.

The normal negative bias on the signal grid G_1 is secured by disposing the usual grid biasing network **20** in the grounded lead of cathode C, and in this modification the positive voltage is supplied to the oscillator anode G_3 through a choke **21** which parallels the tunable oscillator circuit **4**, **5**. The low alternating voltage side of the tunable oscillator circuit is grounded. A condenser **22** connects the oscillator anode side of coil **21** to the high alternating voltage side of the tunable circuit **4**, **5**, and the plate P receives its positive voltage from the source B, as in the case of Fig. 1.

The AVC voltage is supplied to the signal grid G_1 through any desired type of automatic volume control circuit, and in Fig. 3 the usual AVC rectifier is represented by a square, the negative side of the impedance (not shown) which develops the control voltage being connected by the AVC lead to the low alternating voltage side of the tunable signal circuit **1**, **2**. The AVC network is grounded in order to provide a path for the fixed negative bias impressed on the signal grid G_1, and numerals **30** and **30'** designate the pulsating current filter elements usually employed in the AVC network. It is to be clearly understood that the invention is not limited to the use of any specific type of AVC circuit, but that the legend "AVC rectifier" is intended to represent any well known form of rectifier circuit which is adapted to convert the received signal energy into a direct current voltage proportional to the amplitude of the received signal energy at all times.

In this way the negative bias of the signal grid G_1 is increased when received signal amplitude increases, and is decreased when the signal amplitude decreases. Thus, the gain of tube **2R7** is a maximum when weak signals are received, and is a minimum when strong signals are received, this gain variation resulting in a compensation of fading effects and other undesired effects. Since those skilled in the art are well acquainted with the types of AVC systems which may be employed in the arrangement shown in Fig. 3, it is not believed necessary to make any further description of this element of the receiving system.

The arrangement shown in Fig. 3 permits the automatic volume control voltage to be applied to the signal grid G_1 without reducing the strength of the local oscillations generated. This is so because the electron current to the oscillator electrodes is not reduced by placing a large negative bias on G_1. Large bias on G_1 merely prevents current from reaching the plate, the loss of plate current being compensated by the increase of current to G_2.

In each of the arrangements shown in this application the frequency changing function, or heterodyning function, is accomplished by electron coupling. It will be observed that, as in Fig. 1, the electron stream emanated from the cathode C to the plate P is modulated in accordance with the signal currents impressed upon signal grid G_1. These modulated electron currents are further affected by the oscillations generated in the local oscillator section of the tube. The resultant of these effects on the electron stream is applied to the plate P. The various frequencies produced in the circuit associated with the plate P are rejected with the exception of the intermediate frequency.

In the case of Fig. 3 the reverse action takes place; that is to say, the signal currents modulate the oscillation frequency-modulated electron currents flowing to the plate P. It is to be clearly understood that these aforementioned statements concerning the nature of the frequency changing action of tube **2R7** are merely explanatory and theoretical in nature. Reference is made to the application of J. C. Smith, Serial No. 654,421, filed January 31, 1933 for a more detailed explanation of the frequency changing phenomenon which occurs in the **2A7** or pentagrid converter tube.

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, an electron discharge tube comprising a tube envelope of the evacuated type, a cathode disposed within the tube envelope, a plate disposed within the tube envelope and spaced from said cathode, at least five cold electrodes disposed between said cathode and plate, one of said cold electrodes being adapted to function as an oscillator anode, a second of said cold electrodes being adapted to function as an oscillator grid and being disposed between the oscillator anode and the said plate, means for positively charging two of said cold electrodes and surrounding the oscillator anode and oscillator grid with a positive potential surface, the other of said cold electrodes being adapted to function as a signal grid and being disposed outside said positive surface, means for impresing a modulated carrier frequency voltage on said signal grid, a circuit tunable to a local oscillation frequency connected to said oscillator anode, and means including the inherent capacity between said oscillator anode

and oscillator grid to provide coupling between these last two named electrodes.

2. In combination, an electron discharge tube comprising a tube envelope of the evacuated type, a cathode disposed within the tube envelope, a plate disposed within the tube envelope and spaced from said cathode, at least five cold electrodes disposed between said cathode and plate, one of said cold electrodes being adapted to function as an oscillator anode, a second of said cold electrodes being adapted to function as an oscillator grid and being disposed between the oscillator anode and the said plate, two of said cold electrodes being positively charged and surrounding the oscillator anode and oscillator grid, means for applying said positive charge, the other of said cold electrodes being adapted to function as a signal grid, a leak resistor disposed within said tube envelope connected between the said oscillator grid and said cathode, a circuit tunable to the incoming signal frequency connected between said signal grid and cathode, and a circuit tunable to a local oscillation frequency coupled to said oscillator anode, and said oscillator grid having a negative transconductance with respect to the oscillator anode.

3. In combination, an electron discharge tube comprising a tube envelope of the evacuated type, a cathode disposed within the tube envelope, a plate disposed within the tube envelope and spaced from said cathode, at least five cold electrodes disposed between said cathode and plate, one of said cold electrodes being adapted to function as an oscillator anode, a second of said cold electrodes being adapted to function as an oscillator grid and being disposed between the oscillator anode and the said plate, two of said cold electrodes being positively charged and surrounding the oscillator anode and oscillator grid, means for applying said positive charge to the said two electrodes, the other of said cold electrodes being adapted to function as a signal grid, said tube having associated with it a tunable signal input circuit connected between said cathode and said signal grid, a tunable local oscillation circuit connected to one of said oscillator electrodes, and solely capacity coupling being provided between said oscillator anode and said oscillator grid.

4. In a multi-range converter circuit, a converter tube of the type including a cathode, signal grid and a plate, a beat frequency circuit connected to said plate, and a signal input circuit connected between the signal grid and cathode, a pair of oscillator electrodes disposed in the electron stream between the cathode and plate, said oscillator electrodes comprising an electrode adapted to function as an oscillator anode, and an electrode adapted to function as an oscillator grid, said oscillator anode being disposed closer to the cathode than the oscillator grid, a constant positive potential screen disposed between said cathode and oscillator anode for producing a negative transconductance between said oscillator electrodes, means providing purely capacity coupling between the two oscillator electrodes, a tunable local oscillator network connected to at least one of said oscillator electrodes, said tunable network consisting of a variable tuning condenser, a plurality of coils having different inductances and means whereby one only or two of said coils may be connected in shunt with said condenser.

5. An electron discharge tube comprising a tube envelope of the evacuated type, a cathode disposed within the tube envelope, a plate disposed within the tube envelope and spaced from said cathode, at least five cold electrodes disposed between said cathode and plate, one of said cold electrodes being adapted to function as an oscillator anode, a second of said cold electrodes being adapted to function as an oscillator grid and being disposed between the oscillator anode and the said plate, two of said cold electrodes being positively charged and surrounding the oscillator anode and oscillator grid, means for applying said positive charge, the other of said cold electrodes being adapted to function as a signal grid and being disposed between said oscillator grid and plate, said tube having associated therewith a signal input circuit connected between the signal grid and the cathode, a tunable oscillator circuit connected to one of said oscillator electrodes, and an automatic volume control network electrically associated with said signal grid for automatically varying the conversion gain of the tube in response to variations in the received signal amplitude.

6. A frequency converting device comprising the combination of a vacuum tube having a cathode, an oscillator anode, a grid located between said cathode and anode, means for applying a positive potential to said grid, a plate, an oscillator grid located between said oscillator anode and plate and arranged to have a negative transconductance with respect to said oscillator anode, a signal control grid, a capacitively reactive feedback circuit connected between said oscillator grid and anode, a circuit tuned to a local oscillation frequency coupled to said oscillator anode, said circuit being caused to oscillate by the feedback through said capacitively reactive circuit, a circuit tuned to an incoming signal frequency coupled to said signal control grid and an output circuit connected to said plate.

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