April 21, 1936. W. A. HARRIS 2,038,285

PARALLEL PUSH-PULL CONVERTER CIRCUITS

Filed Oct. 17, 1934 3 Sheets-Sheet 1

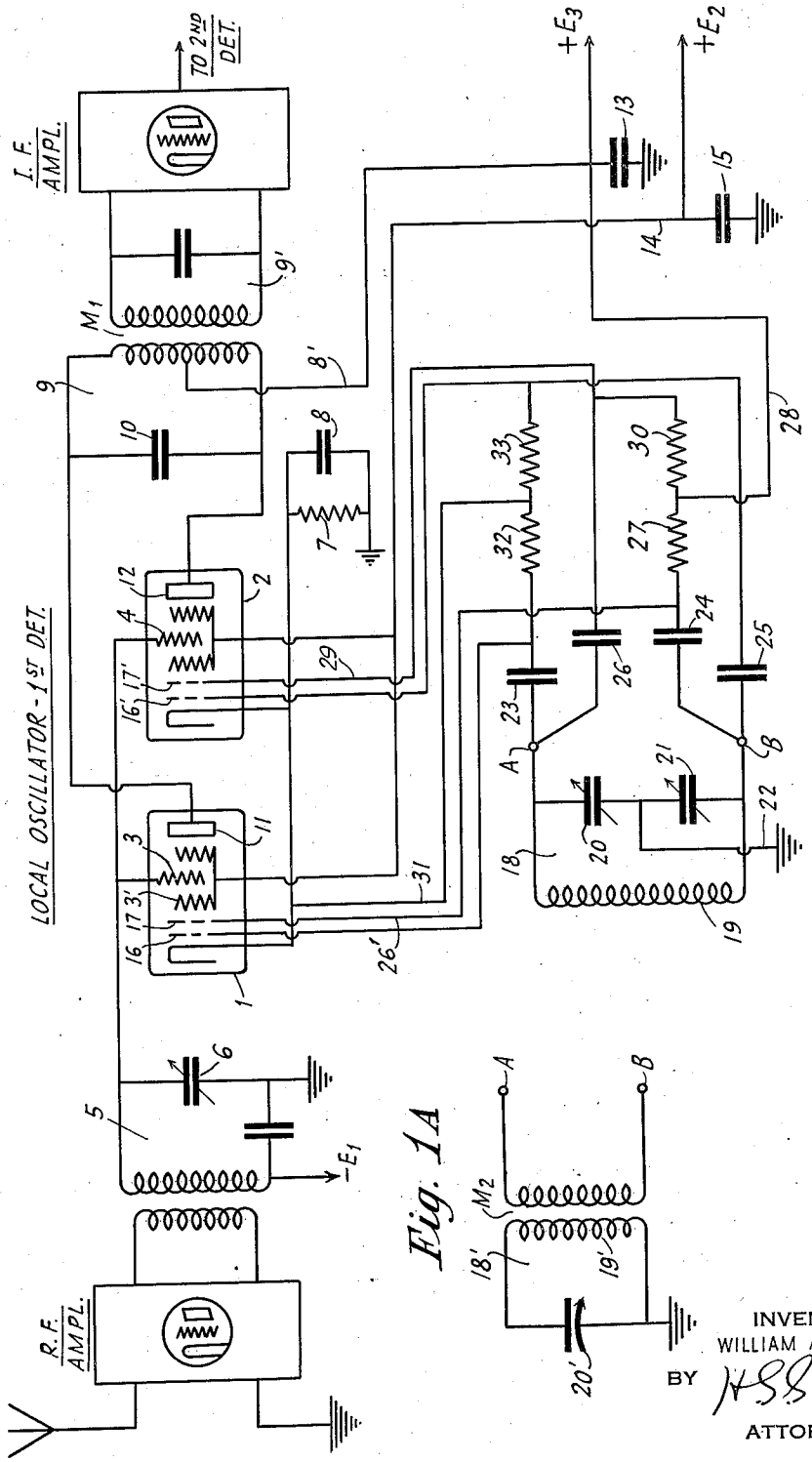

Fig. 1

Fig. 1A

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Fig. 2

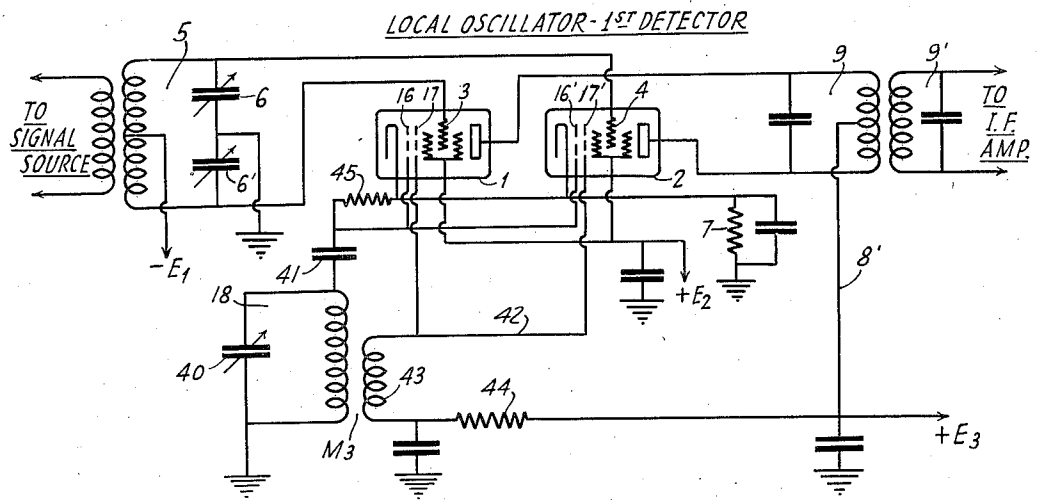

Fig. 3

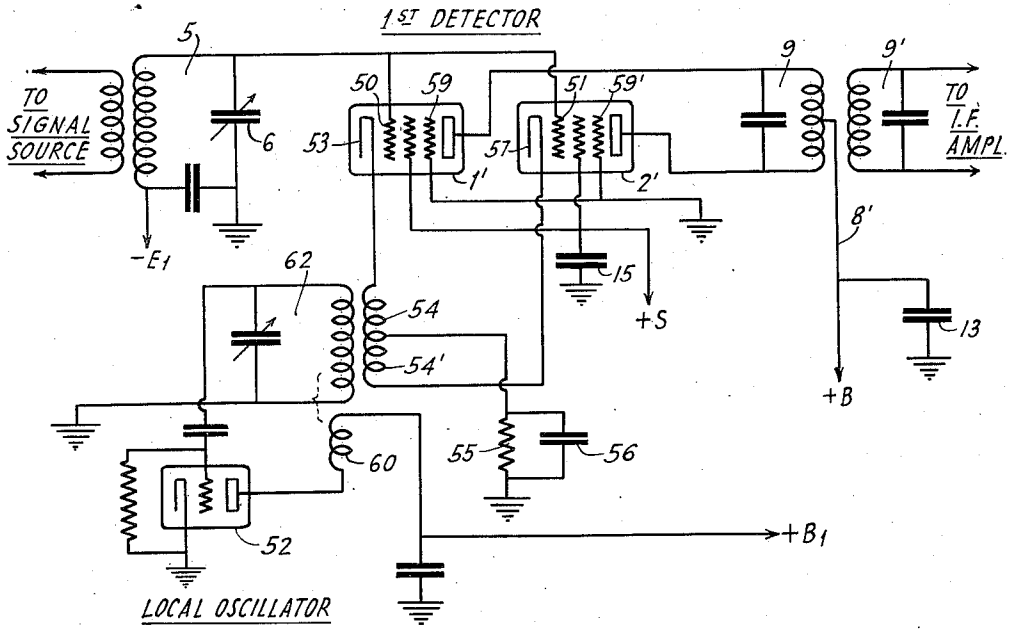

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Fig. 4

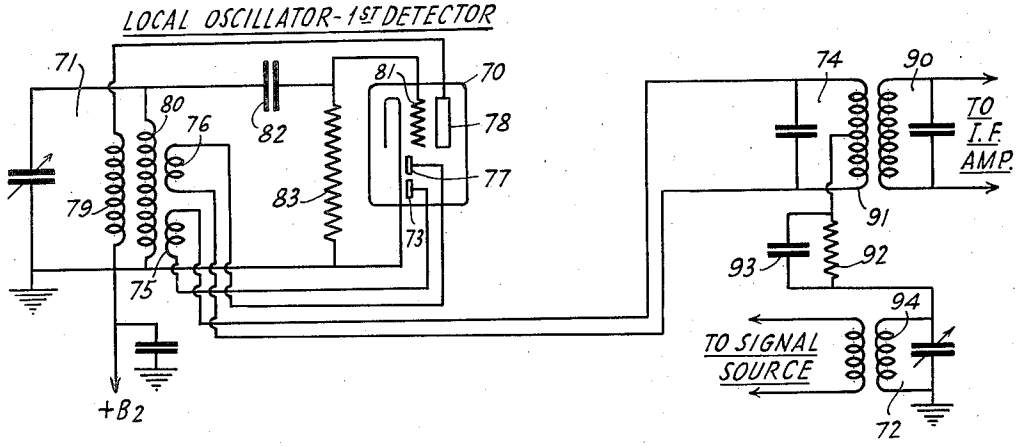
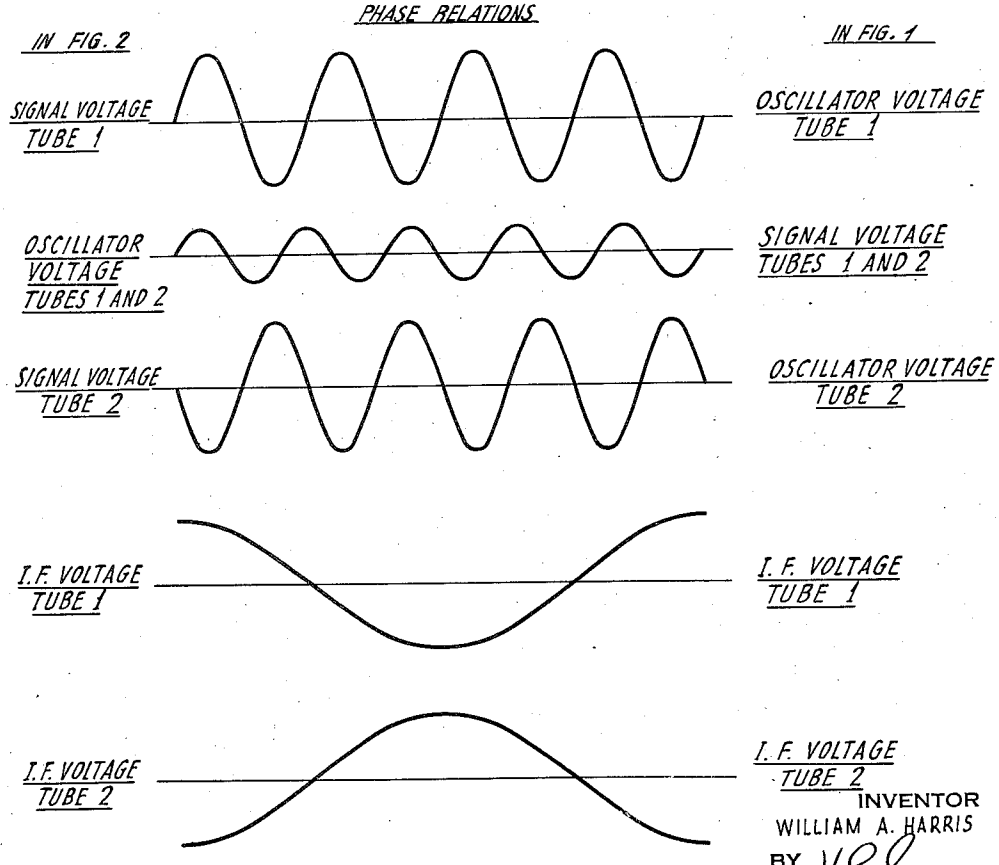


Fig. 5



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Patented Apr. 21, 1936 2,038,285

UNITED STATES PATENT OFFICE

2,038,285

PARALLEL PUSH-PULL CONVERTER CIRCUITS

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Application October 17, 1934, Serial No. 748,606

5 Claims. (Cl. 250—20)

My present invention relates to signal frequency changer networks, and more particularly to parallel push-pull converter circuits adapted for use in superheterodyne receivers.

Spurious couplings between the local oscillator and signal frequency circuits of superheterodyne converter networks cause considerable difficulty. This has been found especially troublesome in converter networks used in multi-range receivers, and wherein the converter network utilized a 6A7, or pentagrid, type tube. Most of the spurious couplings, in the latter case, have been found to be due to the effect of modulation of the space charge, in the vicinity of the signal control grid, at the local oscillator frequency. It was, additionally, found that some spurious coupling was caused by residual inter-electrode capacitances within the converter tube.

Now, I have discovered that the effect of such undesired spurious couplings, whether due to capacity and/or space charge coupling, can be practically eliminated by employing a pair of converter tubes, or elements, in the converter network, and reversing the phase relation between local oscillator voltage and signal voltage in one of the tubes with respect to the other.

Therefore, it may be stated that it is one of the primary objects of this invention to provide a converter network for a superheterodyne receiver wherein the network includes at least two tubes, or devices, arranged in circuits such that if the signal voltage is applied to the appropriate electrodes of the two devices in a parallel arrangement, then the local oscillator voltage is applied in push-pull fashion, and, conversely, if the oscillator voltage is applied to the two devices in parallel, signal voltage is applied with the devices in push-pull.

Another important object of the present invention is to provide a combined local oscillator-first detector network for a superheterodyne receiver, wherein the network includes a pair of pentagrid tubes arranged in parallel push-pull relation, and the connections between the tubes are such that the phase relation between the oscillator voltage and signal voltage is reversed in one of the tubes as compared to the other.

Another object of the invention is to provide a method of substantially minimizing, or eliminating, the effect of capacity and/or space charge couplings in superheterodyne converter networks, the method including impressing upon one of a pair of electron discharge devices employed in the network local oscillator and signal voltages in phase opposition relative to the phase relation between the same voltages impressed on the other device.

Still another object of the invention is to provide a superheterodyne converter circuit which includes an electron discharge tube provided with a pair of diode electrode sections and an electrode section including at least one grid, the last section having circuits operatively associated therewith to enable it to function as a local oscillator, and the diode sections having circuits for rendering them operative as a parallel push-pull converter network.

Still other objects of the invention are to improve generally the efficiency of converter networks, and to particularly provide such networks which are not only reliable in operation, but economically manufactured and assembled in superheterodyne 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, as to both its organization and method of operation will best be understood by reference to the following description taken in connection with the drawings in which I have indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawings:—

Fig. 1 shows a circuit diagram of a converter network embodying the invention,

Fig. 1A shows an alternative local oscillator circuit for the network of Fig. 1,

Fig. 2 illustrates a modification of the network shown in Fig. 1,

Fig. 3 represents another modification of the invention,

Fig. 4 shows a further modification,

Fig. 5 graphically shows the phase relations in Figs. 1 and 2.

Referring now to the accompanying drawings, wherein like reference characters in the different figures represent similar circuit elements, there is shown in Fig. 1 that portion of a superheterodyne receiver preceding the second detector. The signal collector, radio frequency amplifier and intermediate frequency amplifier are schematically represented. Those skilled in the art are well aware of the construction of these networks. The radio frequency amplifier may include one, or more, tunable stages. The network between the tunable amplifier and the intermediate frequency amplifier includes the subject matter of the present invention, and functions as a combined local oscillator-first detector circuit. The

latter includes a pair of tubes 1, 2 having their circuits so arranged that the effect of spurious couplings between the local oscillator and signal circuits is practically eliminated.

This is accomplished by connecting the signal control grids 3 and 4 of the tubes in parallel with the tunable signal input circuit 5. The latter includes a variable tuning condenser 6 connected between ground and the high alternating voltage side of circuit 5. The cathodes of tubes 1, 2 are connected together, and grounded through a resistor 7 shunted by a radio frequency by-pass condenser 8. Part of the biasing voltage for the signal control grids 3 and 4 is obtained from the drop in this resistor, and additional biasing voltage $-E_1$ may be supplied as indicated. This additional bias may be derived from an automatic volume control circuit. The intermediate frequency output of the two tubes is derived from a circuit 9 maintained fixedly tuned to the operating intermediate frequency by a condenser 10. The plate 11 of tube 1 and the plate 12 of tube 2 may be connected respectively to the two sides of circuit 9. The following input circuit 9', also tuned to the intermediate frequency, is coupled to circuit 9.

The center tap on the primary coil of the coupling transformer M_1 is grounded through a path including lead 8' and condenser 13. The lead 8' is further connected to a point of positive voltage E_3, and thus the plates 11, 12 are maintained at a desired positive voltage. The signal grid of each tube is disposed between a pair of positive screen grids thereby providing a positive shielding field around each signal grid. The screen grids of the tubes are connected to a point of positive voltage E_2 through a lead 14, and a radio frequency by-pass condenser 15 is connected between ground and the lead 14. The value of E_2 will, in general, be less than the value of E_3.

The local oscillator section of each of tubes 1 and 2 comprises a cathode, an oscillator grid and an oscillator anode electrode. Thus, in tube 1, there is disposed between the cathode and the screen grid 3' an oscillator grid electrode 16, and an oscillator anode electrode 17. The numerals 16' and 17' designate the corresponding electrodes of tube 2. The tunable local oscillator circuit is designated by the reference numeral 18, and includes a coil 19 connected in shunt across a pair of variable tuning condensers 20 and 21 in series. The junction of condensers 20 and 21 is grounded by a lead 22. The oscillator grid 16 of tube 1 is connected to one side of local oscillator circuit 18, which side is designated by reference character A, through condenser 23. The oscillator anode 17 of tube 1 is connected to the other side, designated by B, of circuit 18 through condenser 24.

The oscillator grid 16' of tube 2 is connected to point B of the circuit 18 through a condenser 25, and the oscillator anode 17' of tube 2 is connected to point A through condenser 26. The oscillator anodes 17 and 17' are maintained at a desired positive voltage by connecting them to the voltage point E_3 through resistors 27 and 30. Electrode 17 is connected to this voltage point through a path which includes lead 26', resistor 27 and lead 28. The anode 17' is connected to lead 28 through a path which includes lead 29 and resistor 30.

The cathodes of tubes 1 and 2 are connected by lead 31 to a point intermediate the oscillator grid leak resistors 32 and 33, and the latter two resistors are connected in series between oscillator grid 16 and oscillator grid 16'. Thus, it will be observed that grid 16 is connected to the junction of condenser 23 and resistor 32, while grid 16' is connected to the junction of resistor 33 and condenser 25.

It will be observed that the oscillator anode of each of tubes 1 and 2 is reactively coupled to its associated oscillator grid by the oscillator circuit 18, and capacities 23 and 24, or 25 and 26. Furthermore, it will be seen that the oscillator electrodes of tubes 1 and 2 are arranged in push-pull relation, while the signal input circuits are arranged in parallel relation. In other words, the phase relation between oscillator voltage and signal voltage is reversed in one of the converter tubes as compared to the other. The two tubes 1 and 2 are substantially alike in characteristics, and this arrangement results in a practical elimination of capacity and/or space charge coupling as far as their effects on the circuits are concerned.

The tubes 1 and 2 are of the pentagrid converter type of tube. Such tubes are well known to those skilled in the art, and need not be described in any detail. They are known as 6A7 type tubes, and the electron coupling phenomenon occurring within the space current path of each tube has been disclosed by J. C. Smith in application serial No. 654,421, filed January 31, 1933. In using pentagrid converters, such as the 6A7 type tube, in multi-ranged receivers considerable difficulty has been experienced due to coupling between the oscillator and radio frequency circuits. As stated before, most of the spurious coupling of this nature appears to be due to capacity and/or space charge couplings. The circuit arrangement shown in Fig. 1 effectively eliminates the effects of such spurious couplings, and, therefore, renders the superheterodyne type of receiver employing converter circuits more efficient in operation.

Each of the tubes in the circuit of Figure 1 operates in a conventional manner. Thus in the case of tube 1, the following relations exist:

Let the signal voltage impressed on the grid 3 be represented by $E_3 \sin pt$, and the oscillator voltage on the grid 16 by $E_{16} \sin qt$. Then, the output current will contain terms proportional to the product of these voltages, which may be represented as $AE_3E_{16} \sin pt \sin qt$, or the equivalent expression $AE_3E_{16}[\frac{1}{2}\cos(p-q)t - \frac{1}{2}\cos(p+qt)]$. The difference frequency component is $\frac{1}{2}AE_3E_{16}\cos(p-q)t$. The voltage of oscillator frequency developed on the signal grid may be expressed as $BE_{16} \sin qt$, where B is a complex coupling factor which is the resultant of interelectrode capacities, space charge coupling, and circuit impedance. The current of signal frequency appearing in the output circuit may be expressed as $CE_3 \sin pt$, where C is the effective mutual conductance of tube 1 under operating conditions.

The oscillator voltage applied to grid 16' of tube 2 is equal in magnitude, and opposite in phase, to the voltage applied to grid 16 of tube 1, by virtue of the push-pull arrangement of the oscillator circuit and the symmetry of the circuits connected to the two tubes. Consequently, the voltage on grid 16' must be represented by $-E_{16} \sin qt$. The signal voltage applied to grid 4 of tube 2 is the same as that applied to grid 3 of tube 1, represented by $E_3 \sin pt$. The constants involved in the derived expressions will be the same for the two tubes. The difference frequency component of the output current from the tube 2 will be $-\frac{1}{2}AE_3E_{16}\cos(p-q)t$. The voltage of oscillator frequency developed on the signal grid will be $-BE_{16} \sin qt$. The current of signal frequency appearing in the output circuit will be $CE_3 \sin pt$. Since the two signal

control grids 3 and 4 are tied together the voltage $BE_{16} \sin qt$ on grid 3 will be cancelled by the voltage $-BE_{16} \sin qt$ on grid 4. Since the output circuits of the two tubes are connected in a push-pull relationship, the component of difference frequency $-\frac{1}{2}AE_3E_{16} \cos (p-q)t$ from tube 2 will be subtracted from the corresponding component $\frac{1}{2}AE_3E_{16} \cos (p-q)t$ from tube 1, and the resultant difference frequency component will be $AE_3E_{16} \cos (p-q)t$. The current of signal frequency $CE_3 \sin pt$ from tube 2 will be subtracted from the current $CE_3 \sin pt$ from tube 1, thus cancelling this frequency from the output circuit. Also, voltage of the difference frequency will be prevented from appearing on the signal control grids 3 and 4 by a similar mechanism.

In a circuit of the type of Figure 2, coupling between oscillator and signal circuits is avoided, but there will be coupling between the signal frequency circuits and the intermediate frequency circuits. Coupling between oscillator and intermediate frequency circuits is avoided in Figure 2; this is not the case in Figure 1.

Briefly, in a conventional converter circuit employing a single tube, various forms of coupling may exist between signal grid and oscillator, signal grid and output, and oscillator and output. An important object of this invention is to eliminate, or substantially reduce, coupling between signal grid and oscillator, and this is accomplished in all of the circuits shown. The circuits of Figures 1, 3 and 4 will also eliminate, or substantially reduce, coupling between signal grid and output, and direct amplification of the signal frequency, permitting reception of a signal by the superheterodyne method at a frequency equal to, or nearly equal to, the intermediate frequency. The circuit of Figure 2 and other circuits of this type will eliminate coupling between oscillator and output. This feature would be of value in the reception of signals of very low frequencies, or in similar special applications of converter tubes.

The desirability of being able to tune to signals near the intermediate frequency arises in the case of multi-range receivers. Thus, receivers are built which cover a band from approximately 150 to 400 kc., the broadcast band 550 to 1500 kc., and higher frequency bands. The high frequency bands overlap, but there is a gap as indicated from 400 kc. to 550 kc. in which no signals may be received. This is because an intermediate frequency of 465 kc. is used. With the circuit of Fig. 1, it would be feasible to permit overlap between these bands as well as those of higher frequency.

The variable tuning condensers of the radio frequency amplifier network, the condenser 6 and condensers 20 and 21 will be simultaneously adjusted by any uni-control means well known in the art. The receiver may be used in the broadcast range, which is from 550 to 1500 kilocycles, or it may be used with appropriate wave switching arrangements in more than one range of frequency. Such multi-range receivers are well known in the art, and the details thereof are not shown to preserve simplicity of disclosure.

In Fig. 1A, there is shown an alternative local oscillator circuit that may be used in place of circuit 18. In such a case the circuit arrangement to the right of points A and B are similar to that shown in Fig. 1. However, to the left of these two points there is employed a coupling transformer M_2, the secondary thereof being connected between points A and B, and the primary 19' having shunted thereacross a variable tuning condenser 20', the low alternating voltage side of which is grounded. The two variable condensers 20 and 21 are shown in the oscillator circuit 18 of Fig. 1, and the signal circuit of Figure 2, because it is universal practice to ground one side of each tuning condenser. This is a consequence of the mechanical design of ganged condensers. Figure 1A is shown as a means of avoiding the use of an extra tuning condenser.

Fig. 2 shows the manner of arranging the circuits of tubes 1 and 2 when it is desired to have the signal voltage applied to tubes 1 and 2 in push-pull fashion, and when the oscillator voltage is to be applied in parallel fashion. It will be observed that in this case the signal input circuit 5 includes an auxiliary variable tuning condenser 6', and that the junction of the two condensers 6 and 6' is grounded. The signal grid 4 of tube 2 is connected to one side of circuit 5 while the signal grid 3 of tube 1 is connected to the other side of circuit 5. Biasing voltage for the signal control grids 3 and 4 is applied through a center tap on the coil of circuit 5. The local oscillator circuit 18 includes the tuning condenser 40, and the high alternating voltage side of local oscillator circuit 18 is connected to the local oscillator grid electrodes 16, 16' through a condenser 41. The oscillator anodes 17 and 17' of the two tubes are connected together by a lead 42, and are magnetically coupled, as at M_3, to circuit 18. The plates of tubes 1 and 2 are connected to voltage source E_3 through a center tap on the coil of circuit 9, and the oscillator anode electrodes 17 and 17' are connected to the same voltage source through a path which includes the coil 43, and resistor 44. An oscillator grid leak resistor 45 is connected between the cathodes of tubes 1 and 2 and the oscillator grids 16 and 16'.

Although the oscillator voltage is applied to tubes 1 and 2 in parallel, and signal voltage is applied to the tubes in push-pull, it will be noted that the circuit arrangement of Fig. 2 is similar to the arrangement of Fig. 1 in that the phase relation between oscillator voltage and signal voltage is reversed in one of the converter tubes as compared to the other. The operation of the circuit arrangement of Fig. 2 is substantially similar to that shown in Fig. 1.

Fig. 5 graphically shows a comparison of the phase relations existing in tubes 1 and 2 in Figs. 1 and 2. The legends in the figure are self-explanatory. This graphical presentation will clearly show the differences between the circuits of Figs. 1 and 2.

The present invention is not restricted to the case where the network includes tubes functioning both as local oscillators and first detectors. It is equally applicable to the type of network wherein a local oscillator circuit is utilized which includes a tube independent of the first detector tube. Thus, in Fig. 3, tubes 1' and 2' designate tubes of the pentode type whose construction are well known to those skilled in the art. For example, these tubes may be of the 58 type. A 58 type tube is capable of producing, under the proper conditions of grid and local oscillator voltage, a gain in the mixer stage of about ⅓ that which can be obtained from the same tube in an intermediate frequency amplifier stage. In addition, this gain can be controlled as in the case of a radio frequency amplifier by varying the grid bias either from a separate supply, or from a variable resistor in the cathode circuit.

The signal input voltage from input circuit 5, which includes the variable tuning condenser 6, is applied to the signal grids 50 and 51 in parallel. The oscillator voltage derived from the local oscillator tube 52 is applied to the two tubes 1' and 2' in push-pull fashion. Thus, it will be seen that the application of the signal and oscillator voltages to the mixer tubes is similar to that employed in connection with Fig. 1. The plate circuits of the mixer tubes are arranged in the same fashion as shown in Fig. 1, the plate and screen voltage supply source being represented in the case of Fig. 3 by the reference letters B and S.

The cathode 53 of tube 1' is connected to ground through a path which includes coil portion 54 and resistor 55, the latter being shunted by a radio frequency bypass condenser 56. The cathode 57 of tube 2' is connected to the coil portion 54', and it is to be noted that both coils 54 and 54' may be a single coil with an intermediate tap connected to ground through resistor 55. The suppressor grids 59, 59' are connected to ground, and thus are maintained at a negative bias with respect to the cathodes of the mixer tubes.

The local oscillator tube 52 may be of the triode type, for example, and its circuits are conventional in nature. The plate of the oscillator tube is connected to a source of positive voltage B_1 through a path including feedback coil 60. The local oscillator circuit 62 includes a variable tuning condenser, and the feedback coil 60 is magnetically coupled to the oscillator circuit 62. It is not necessary to describe in detail the remaining elements of the local oscillator circuits, because they are well known to those skilled in the art. The inductance coil of local oscillator circuit 62 is magnetically coupled to coils 54 and 54', and it is through this magnetic coupling to the cathodes of the mixer tubes that the oscillator voltage is fed to the mixer tubes.

Although the circuit arrangement shown in Fig. 3 employs a separate local oscillator tube, the phase relationship of the signal and oscillator voltages are the same as in Fig. 1. As stated before, the phase relation between oscillator voltage and signal voltage in one of the converter tubes 1' is reversed as compared to the phase relationships in the other tube 2'.

In the arrangement shown in Figs. 1, 2 and 3 the mixer tubes have been shown as separate tubes. The present invention may be applied with equal facility to a network utilizing a multiple duty tube, wherein the electrodes of a single tube perform the local oscillator, and converter functions. Such a circuit arrangement is illustrated in Fig. 4. The reference numeral 70 designates a multi-function tube of a construction well known to those skilled in the art. The tube usually employs a pair of independent diode sections and a triode, or pentode, section independent of the diode sections. A cathode common to the various sections is utilized within the tube. When the tube 70 includes a triode section, it is of the 55 or 2A6 type. Where the tube 70 includes a pentode section, it is of the 2B7 type. For purposes of simplification in disclosure, the tube 70 is shown as comprising a tube of the 55 type, and wherein the diode sections are utilized as mixer devices.

The signal voltage from tunable circuit 72 is applied to the diode anodes in parallel relationship. Thus, the diode anode 73 is connected to the high alternating voltage side of circuit 72 through a path which includes coil 75, one half of coil 91 and the resistor 92. The diode anode 77 is connected to the same point through a path which includes coil 76, the other half of coil 91 and resistor 92. Resistor 92 is by-passed by condenser 93. The plate 78 of the triode section of tube 70 is connected to a source of positive voltage B_2, through feed back coil 79, and the feed back coil is magnetically coupled to the inductance coil 80 of local oscillator circuit 71. The control grid 81 of the triode section of tube 70 is connected to the high alternating voltage side of circuit 71 through a condenser 82, and the cathode of tube 70 is connected to the grounded side of circuit 71.

A grid leak resistor 83 is connected between the grid side of condenser 82 and the cathode of tube 70. The diode anode 73 is coupled to the oscillator circuit 71 through coil 75, and the diode anode 77 is coupled to the oscillator circuit 71 through coil 76. Connections between the diode anodes and coils 75 and 76 are such that the oscillator voltage is applied to the diode anodes in push-pull relationship. The intermediate frequency output energy of the converter devices is derived from circuit 74 by the circuit 90. Circuit 74 and circuit 90 are fixedly tuned to the operating intermediate frequency. The circuit 74 is connected in push-pull relationship to the diode anodes.

Thus, one side of circuit 74 is connected to diode anode 73 through coil 75, and the other side is connected to diode anode 77 through coil 76; the center tap of coil 91 is connected to ground through a path which includes resistor 92, the resistor being shunted by a radio frequency bypass condenser 93, and signal input coil 94. A negative bias is applied to the diode anodes 73 and 77 by the direct current potential developed across resistor 92 and condenser 93 as a result of rectification of the oscillator voltage applied to the diodes through coils 75 and 76.

Since the signal voltage is applied to the diode anodes in parallel arrangement and the application of the local oscillator voltage is in push-pull arrangement, it will be seen that the phase relationship between signal voltage and oscillator voltage is the same as in the preceding circuit arrangements, but that the specific circuit relationship is that of Fig. 1.

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 a superheterodyne receiver, a converter network including a tube provided with a pair of diode converter sections, each diode section including a cathode and anode, and an oscillator section, including at least a cathode, grid and plate, circuit connections for impressing signal energy of a desired frequency in parallel manner upon the anodes of said diode sections, circuit connections electrically associated with said oscillator section for producing local oscillations of a frequency differing from the signal frequency by a predetermined amount, means for impressing said local oscillations in push-pull manner upon the anodes of said diode sections, and a network tuned to said difference frequency

connected in push-pull relation to the anodes of said diode sections.

2. In a superheterodyne receiver, the combination of a local oscillator network provided with an electron discharge device whose input and output electrodes are reactively coupled to produce local oscillations of a desired frequency, a tunable oscillation frequency determining circuit operatively associated with said device for tuning the oscillator through a frequency range, a first detector network comprising at least one diode having its anode reactively coupled to said tunable oscillation circuit, a tunable signal input circuit operatively associated with the diode electrodes for tuning the diode network through a signal range differing from the oscillator range by a desired intermediate frequency, and an output circuit, resonant to said intermediate frequency, connected to said diode electrodes.

3. In a receiver as defined in claim 2, said first detector network including a second diode, the anodes of said diodes being connected in parallel to the signal input circuit, and the diode anodes being reactively coupled in push-pull relation to the oscillation circuit.

4. In a receiver as defined in claim 2, the electrodes of the diode and said electron discharge device being disposed in a common tube envelope, and a common cathode providing the electrons for the diode anode and the cold electrodes of said discharge device.

5. In a superheterodyne receiver, the combination of a local oscillator network provided with an electron discharge device whose input and output electrodes are reactively coupled to produce local oscillations of a desired frequency, a tunable oscillation frequency determining circuit operatively associated with said device for tuning the oscillator through a frequency range, a first detector network comprising at least one diode having its anode reactively coupled to said tunable oscillation circuit, a tunable signal input circuit operatively associated with the diode electrodes for tuning the diode network through a signal range differing from the oscillator range by a desired intermediate frequency, and an output circuit, resonant to said intermediate frequency, connected to said diode electrodes, a second diode in said first detector network, the diode anodes being connected to said signal and oscillation circuits in such a manner that the phase relation between oscillator voltage and signal voltage is reversed in one of the diodes as compared to the other.

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