

Feb. 3, 1948.

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2,435,541

ULTRA-HIGH FREQUENCY TRIODE CONVERTER

Filed Jan. 26, 1944

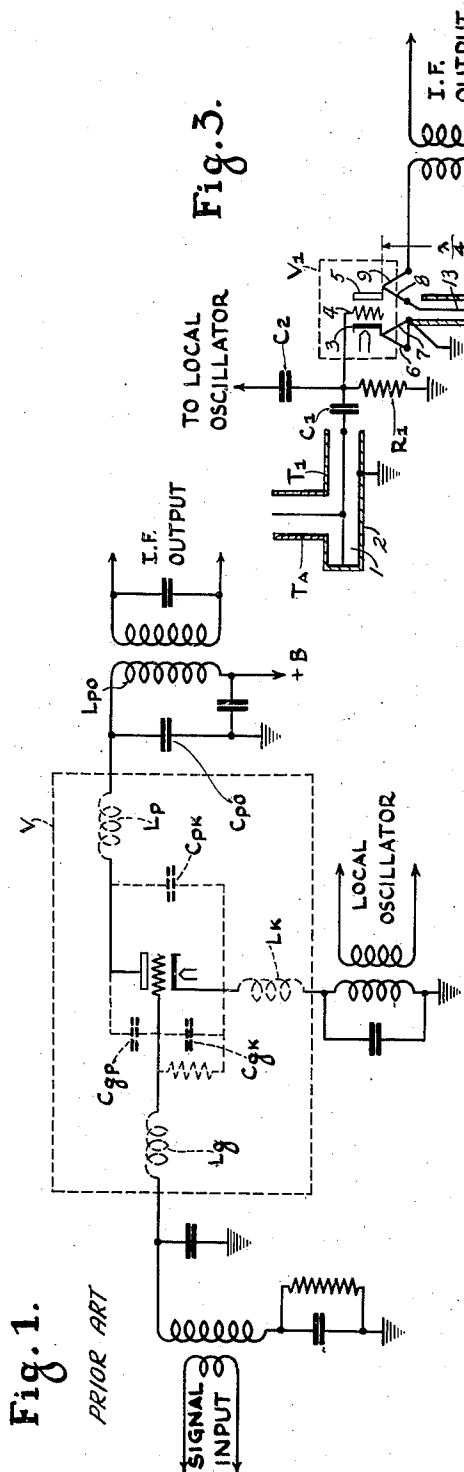


Fig. 3.

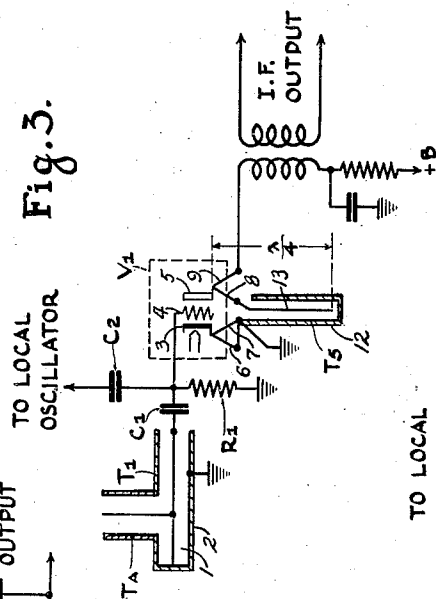


Fig. 4.

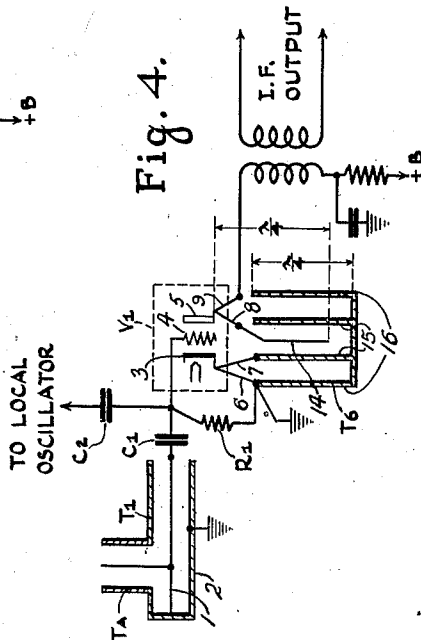
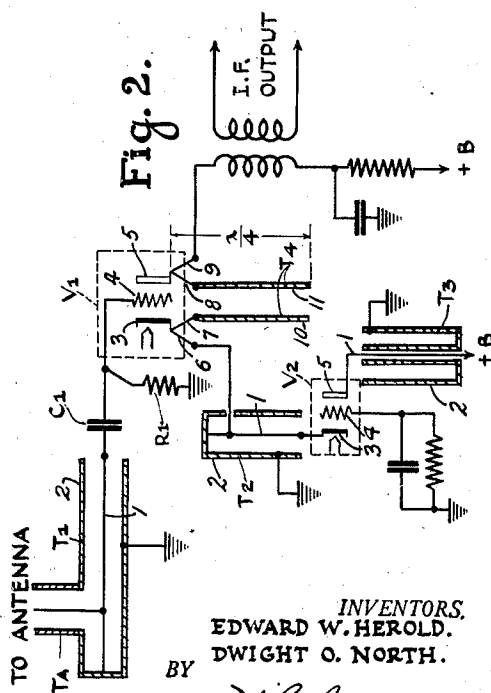


Fig. 2.



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2,435,541

ULTRA HIGH FREQUENCY TRIODE
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Application January 26, 1944, Serial No. 519,730

15 Claims. (Cl. 250-20)

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The present invention relates in general to ultra-high frequency converter systems, and more particularly to such systems utilizing a triode tube of special construction whereby more efficient frequency conversion and improved signal-to-noise ratio are obtained in the reception of signals by the superheterodyne method.

The problem of frequency conversion in a superheterodyne radio receiver has received considerable attention during the last ten years. Until recently, it was believed that tubes for this purpose might always be rather complicated multi-grid structures. However, the high fluctuation noise inherent in such structures has led to a return to simpler tube types such as the triode and the pentode in an attempt to obtain better signal-to-noise ratio. This is particularly true at ultra-high frequencies at which the attainment of large transmitter power is difficult and signals may consequently be weak. It is well known that a triode tube has less fluctuation noise than a pentode of comparable structure but it suffers from feedback effects which are serious even in converter operation.

It is, therefore, one of the main objects of our present invention to provide improved circuits using special triode tubes for converter operation and wherein feedback effects are greatly reduced, particularly at ultra-high frequencies.

Another object of the invention is to provide the cathode and plate of the converter tube each with a pair of leads which have connected to them suitable external elements for eliminating detrimental feedback effects.

Another object is to provide a high frequency converter system utilizing a tube having a control grid, a cathode, and an anode provided with two leads, and wherein the output circuit tuned to the intermediate frequency is connected to one of the anode leads, and a path of low impedance for signal frequencies but high impedance for intermediate frequencies is connected between the cathode and the anode through the second anode lead.

A further object is to provide, in the high frequency converter system mentioned above, a low impedance path constituted by an open transmission line equivalent to an open quarter-wave section at signal frequencies, one conductor of which is connected to the cathode and the other conductor of which is connected to the second of the anode leads.

A still further object is to provide, in the high frequency converter system mentioned above, a low impedance path constituted by a concentric-

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conductor resonant line equivalent to a quarter-wave open section at signal frequencies, the inner cylinder of which is insulated throughout its length and connected at its near end to the second of the anode leads and the outer cylinder of which is connected to the cathode.

These and other objects and advantages of the invention will be apparent from the following specification when taken with the accompanying drawings, in which:

Fig. 1 represents a conventional high frequency triode converter circuit which will serve to explain the theory underlying the present invention;

Fig. 2 discloses the circuit of an ultra-high frequency converter stage in accordance with the invention, and

Figs. 3 and 4 are modified forms of the converter stage shown in Fig. 2.

In the triode used in a converter stage as herein contemplated, the signal is applied to the control grid, and a local oscillator voltage is also applied, either to the cathode through a low impedance circuit, or to the control grid. The intermediate frequency output is taken from the plate. Circuit analysis shows that an inductive reactance in the cathode circuit will cause a reduced input impedance, so that it is preferable to introduce the local oscillator voltage across the signal input circuit or else keep the effective cathode impedance capacitive in character. The effect of a cathode impedance on the input circuit comes about through the grid-to-cathode internal admittance. In the same way, an impedance in the plate circuit also affects the input impedance through the grid-to-plate capacitance.

We may schematically represent a conventional triode converter at high frequencies by a circuit similar to that in Fig. 1. The triode V is shown by the dotted line block representing the envelope of the tube, with internal capacitances C_{gk} , C_{pk} , and C_{pD} . The lead inductances are shown as L_g , L_k and L_p . The I-F. output circuit is connected to the plate. When a signal is applied to the control grid and a local oscillator is applied to the cathode, as shown, the tube operates as a modulator, and an I-F. current flows in the plate circuit, giving rise to an I-F. output voltage which may subsequently be utilized in the manner well known in superheterodyne receivers. In addition, however, there is an alternating current flow from cathode to plate of the tube at the signal frequency. It is the latter current which gives rise to a signal frequency voltage across C_{pk} , C_{pD} , L_p , and L_k . An important result of these signal

frequency voltages lies in the resulting feedback currents flowing through the input signal circuit. To a first approximation the effect of such feedback is as though the input circuit were modified by the addition of shunt impedance, the conductance of which is often positive in sign so as to load the input circuit.

Inspection of Fig. 1 will show that the chief feedbacks are caused by a signal frequency voltage existing between the cathode and ground, and by a signal frequency voltage between the plate and ground. Neither of these voltages is of any advantage in normal converter operation and our invention is directed toward the elimination of both.

Our invention is based upon the following considerations. If the internal plate-to-cathode capacitance, C_{pk} , were large enough, the signal frequency current flowing into the plate of the tube would be bypassed directly to the cathode and could not give rise to large signal frequency voltage drops. However, such a large capacitance would seriously reduce the I-F. output circuit impedance and/or band width and would merely mitigate one defect while increasing another. It would also appear that, if a small series inductance could be placed in series with C_{pk} so as to resonate at the signal frequency, the signal frequency currents could be bypassed, in this case, without detriment to the I-F. output. Since C_{pk} is an inter-electrode capacitance, such series tuning is not possible. A partial improvement is possible by a series resonance of the circuit L_p , C_{po} , L_{po} . As an aid in achieving this, the primary L_{po} of the I-F. transformer may be so wound as to provide a series resonance at the signal frequency. This is possible since the signal frequency is usually well above the first natural frequency of the I-F. inductance, and a sectionalized winding or even proper tube or circuit leads may offer the correct inductive reactance to cancel the capacitive coil reactance. A more effective design would separately series-tune the plate to ground and the cathode to ground to eliminate the chief feedbacks mentioned above.

In examining the triode converter in the light of these considerations, it occurred to us that an even more satisfactory method of providing a path from plate to cathode, of low impedance at signal frequency and high impedance at intermediate frequency, would be the direct connection of a separate circuit, or its equivalent, directly between these two points. Of course, such a circuit could presumably be built inside the tube, but this would not permit adjustment to different frequencies and might not be commercially useful. For these reasons, we have made use of a modification in the tube structure whereby additional leads are brought out from the cathode and from the plate as shown in Fig. 2 for triode tube V_1 . One pair of leads, according to our invention, is then used for the normal converter connections, as in Fig. 1, while the other pair is used to provide a low impedance path, series-tuned at signal frequency and open-circuited at intermediate frequency, from plate to cathode. In this way, there can be no signal frequency currents or signal frequency voltages in the first pair of leads due to the plate current flow and all feedback effects are eliminated, provided only that the two pairs of leads can be externally separated by high impedance connections. We have found it possible to do this.

At ultra-high frequencies, the effect of a series-tuned circuit is most easily obtained by trans-

mission line circuits. For example, a pair of insulated uniformly spaced wires of a length just equal to a quarter of the wavelength, behaves as a series-tuned circuit across either end. We make use of such an arrangement in the ultra-high frequency converter stage shown in Fig. 2. In this figure T_1 , T_2 and T_3 are resonant circuits of the concentric transmission line type each comprising an inner conductor 1 and an outer conductor 2. V_1 is the triode converter tube and V_2 is a local oscillator tube each comprising a cathode 3, a control grid 4 and a plate or anode 5. The cathode 3 of converter tube V_1 is provided with a pair of leads 6, 7 and the plate 5 of this tube is provided with a pair of leads 8, 9. The circuit T_4 , comprising a pair of conductors 10 and 11 which are connected, respectively, to cathode lead 7 and anode lead 8, is an open quarter-wave parallel line at signal frequency for the purpose of providing a low impedance path for currents of this frequency from the plate 5 to the cathode 3 of tube V_1 . In operation, circuit T_1 is tuned to the signal frequency and serves as an antenna coupling transformer from the transmission line T_A to the grid 4 of tube V_1 . The capacitance C_1 and resistance R_1 serve as a grid condenser and leak, respectively, to provide appropriate bias for the grid 4 of tube V_1 . One cathode lead 6 of tube V_1 is connected to a point on the inner conductor 1 of the local oscillator tuning lines T_2 and serves to impress the local oscillator voltage on the cathode 3 of tube V_1 . Circuits T_2 and T_3 and the tube V_2 represent a typical local oscillator. It is, of course, obvious, that the resonant transmission line T_4 is preferably adjustable in electrical length to tune to the desired incoming signal frequency. Adjustment of electrical length may be effected by adjustment of physical length of the line, by adjustment of a variable capacitance across the line, or by any other means. This circuit may be enclosed in a shield, or, in some instances, may be a concentric line in place of the parallel wire-line shown.

Another V.-H.-F. converter circuit incorporating our invention is shown in Fig. 3. This differs from the previous circuit in that a local oscillator (not shown) is loosely coupled to the signal input circuit T_1 through a small capacitance C_2 . In this circuit, the cathode 3 of tube V_1 through lead 7 is connected to the outer, grounded conductor 12 of a concentric, quarter-wave line T_5 . The inner conductor 13 of this line is an open circuit at its far end and is connected to the plate 5 of tube V_1 at its near end through lead 8, as shown. Two cathode leads are not essential in this circuit, although they are still desirable to reduce the lead losses. The circuit of Fig. 3 does not completely eliminate feedback effects in the cathode lead, however, since the currents through the low impedance plate-to-cathode path may set up a signal frequency voltage between cathode and ground.

The basic purpose behind our invention is to provide (a) a low impedance path, at signal frequency, between plate and cathode and (b) a second and independent low impedance path between the cathode and the low side of the input circuit. In Fig. 3, our first purpose is accomplished, but the second is not necessarily achieved if the cathode lead inductance is appreciable. A more satisfactory solution in eliminating the cathode lead feedback is shown in the circuit of Fig. 4 where the circuit T_5 corresponding to T_5 in Fig. 3 is composed of three concentric elements, namely, an inner conductor 14, an inter-

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mediate element or cylinder 15 and an outer cylinder 16. The cathode 3 of V₁ is connected to ground through one lead 6, while the second cathode lead 7 is connected to the intermediate element 15. The outer concentric cylinder 16 is connected to the first cathode lead 6, and the inner conductor 14 is insulated throughout its length and connected to the plate 5 of tube V₁ through the additional plate lead 8. Its electrical length is adjusted to be equivalent to a quarter-wave open section. The intermediate cylinder 15 and the outer cylinder 16 are connected electrically at the far end and are adjusted to be electrically a quarter-wave long. By this arrangement, the plate 5 and cathode 3 are connected through the low impedance of the inner two concentric elements 14 and 15 whereas the two cathode leads 6 and 7 are separated by the high impedance shorted quarter-wave line formed by the outer two cylinders 15 and 16.

It will be apparent that many modifications of our basic idea can be made by the skilled worker in the high frequency field and such variations will have advantages in particular cases. We have chosen to include herein only those arrangements which are believed to illustrate our invention most simply and directly.

What we claim is:

1. An ultra-high frequency converter system utilizing a tube having a control grid, a cathode and an anode, and in which two leads are provided each for the cathode and anode, characterized in that between one of the anode leads and one of the cathode leads there is connected a series-tuned, low-impedance path for signal frequencies, and further characterized in that the cathode is effectively connected to ground through the other cathode lead and the anode is connected to output circuit through the other anode lead.

2. An ultra-high frequency converter system as defined in claim 1 wherein the low impedance path is constituted by a two-conductor resonant line approximately one-quarter of a wavelength long.

3. An ultra-high frequency converter system as defined in claim 1 wherein the low impedance path is constituted by a concentric conductor resonant line approximately one-quarter of a wavelength long, the inner conductor of which is an open circuit at its far end and connected to said anode lead at its near end, the outer conductor being grounded and connected to said cathode lead.

4. An ultra-high frequency converter system utilizing a tube having a control grid, a cathode and an anode, and in which two leads are provided each for the cathode and anode, characterized in that between an anode lead and a cathode lead there is connected a series-tuned, low impedance path for signal frequencies, and between the two cathode leads there is connected a high impedance path.

5. An ultra-high frequency converter system utilizing a tube having a control grid, a cathode and an anode, and in which two leads are provided each for the cathode and anode, characterized in that for preventing the existence of a signal frequency voltage between anode and cathode there is connected, between an anode lead and a first cathode lead, a path of low impedance for signal frequencies and high impedance for intermediate frequencies, and, for eliminating the flow of signal frequency currents from said anode through the second cathode lead, there is con-

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nected between the two cathode leads a high impedance path.

6. An ultra-high frequency converter system comprising a tube having a control grid, a cathode and an anode, said cathode and anode being provided each with two leads, a signal frequency input circuit connected to the control grid, a source of locally-generated oscillations connected to one of the cathode leads, an output circuit tuned to the intermediate frequency connected to one of the anode leads, and a series-tuned, low impedance path for signal frequencies connected between the remaining two anode and cathode leads.

7. An ultra-high frequency converter system as defined in claim 6 wherein the low impedance path is constituted by a two-conductor resonant line approximately one-quarter of a wavelength long.

8. An ultra-high frequency converter system comprising a tube having a control grid, a cathode and an anode, said cathode and anode being provided each with two leads, a signal frequency input circuit connected between the control grid and one of the cathode leads, a source of locally-generated oscillations coupled to the control grid, an output circuit tuned to the intermediate frequency connected to one of the anode leads, and a series-tuned, low impedance path for signal frequencies connected between the remaining anode lead and the other cathode lead.

9. An ultra-high frequency converter system as defined in claim 8 wherein the low impedance path is constituted by a concentric conductor resonant line one-quarter of a wavelength long, the inner conductor of which is an open circuit at its far end and connected to said anode lead at its near end, the outer conductor being connected at its near end to said other cathode lead.

10. An ultra-high frequency converter system comprising a tube having a control grid, a cathode and an anode, said cathode and anode being provided each with two leads, a signal frequency input circuit connected between the control grid and the first cathode lead, a source of locally-generated oscillations coupled to the control grid, an output circuit connected to the anode through one of its leads, and means for minimizing the flow of signal frequency currents from said anode through any portion of the input circuit and its connecting leads, said means including a transmission line consisting of three concentric cylinders, the outer of which is connected to the first cathode lead, the intermediate cylinder being connected to the second cathode lead, the inner cylinder being equivalent to a quarter-wave open section, insulated throughout its length and connected to the anode through the second anode lead, and the intermediate and outer cylinders being connected electrically at the far end and being equivalent to a quarter-wave shorted section.

11. A high frequency converter system comprising a tube having a control grid, a cathode, and an anode, said anode being provided with two leads, a signal frequency input circuit connected between the control grid and the cathode, a source of locally-generated oscillations connected to an electrode of said input circuit, an output circuit tuned to the intermediate frequency connected to one of the anode leads, and a path of low impedance for signal frequencies but high impedance for intermediate frequencies connected between the cathode and the anode through the second anode lead.

12. A high frequency converter system as defined in claim 11 wherein the low impedance path is constituted by an open transmission line equivalent to an open quarter-wave section at signal frequencies, one conductor of which is connected to the cathode, the other conductor being connected to the second of the anode leads.

13. A high frequency converter system as defined in claim 11 wherein the low impedance path is constituted by a concentric conductor resonant line equivalent to a quarter-wave open section at signal frequencies, the inner cylinder of which is insulated throughout its length and connected at its near end to the second of the anode leads, the outer cylinder being connected to the cathode.

14. A high frequency superheterodyne converter circuit utilizing a tube having a cathode electrode, control grid electrode, anode electrode, and at least one lead to each of these electrodes, wherein the cathode lead is connected to ground, a signal input circuit is connected between the control grid and ground, an intermediate frequency circuit is connected between the anode and ground, and wherein a low impedance path for signal frequencies is provided between anode and ground by the use of an intermediate frequency circuit which has high impedance at intermediate frequency but which is in series resonance with the anode electrode lead at the signal frequency.

15. A high frequency superheterodyne con-

verter circuit utilizing a tube having a cathode and an associated lead thereto, a control electrode and a lead thereto, and an anode with a lead thereto, wherein a signal input circuit is connected between control grid and ground, an intermediate frequency circuit is connected between the anode lead and ground and wherein a low impedance path at signal frequency is provided between anode and ground and a second low impedance path at signal frequency is provided between cathode and ground, said low impedance paths being obtained by a series resonance at signal frequency of the intermediate frequency circuit and the anode lead and by a circuit connected between the cathode lead and ground so as to provide a series resonant path at signal frequency between cathode and ground.

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