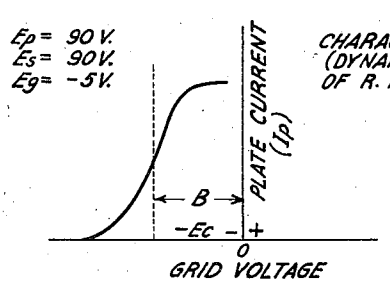
Sept. 8, 1936. W. S. BARDEN 2,053,414

HETERODYNE RECEIVING SYSTEM

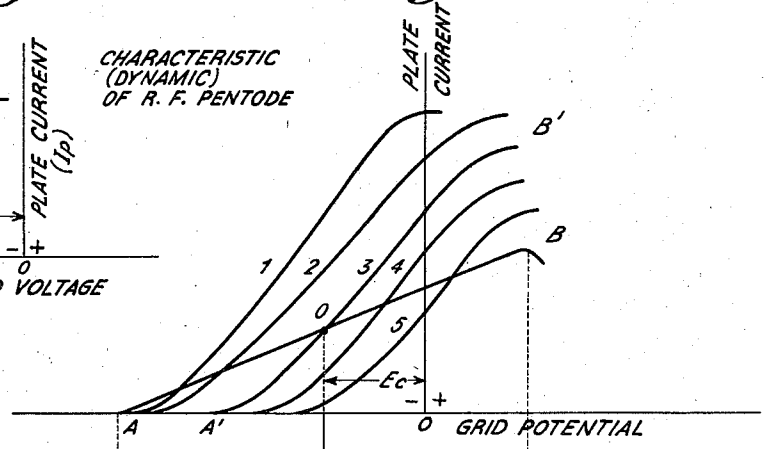
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Fig. 1a



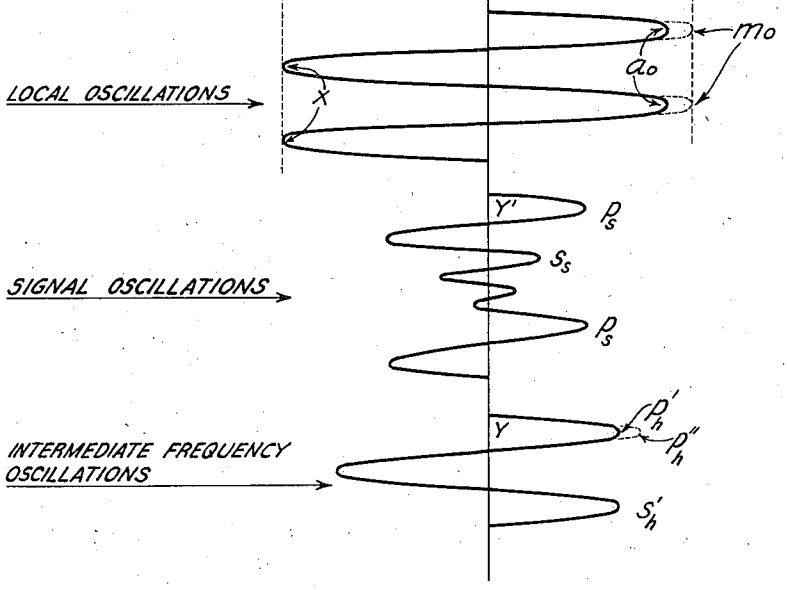
CHARACTERISTIC (DYNAMIC) OF R. F. PENTODE

Fig. 1



CURVES 1, 2, 3, 4, 5 ARE STATIC CHARACTERISTICS OF A TRIODE FOR DIFFERENT FIXED VALUES OF PLATE POTENTIAL.

CURVE A O B IS DYNAMIC CHARACTERISTIC OF TRIODE OSCILLATING, AND CORRESPONDING TO CURVE 3



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HETERODYNE RECEIVING SYSTEM

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Fig. 2

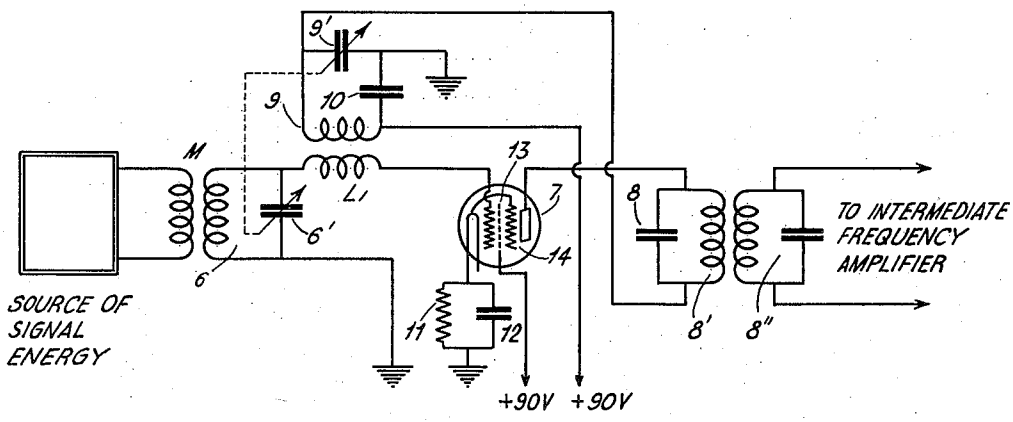


Fig. 3

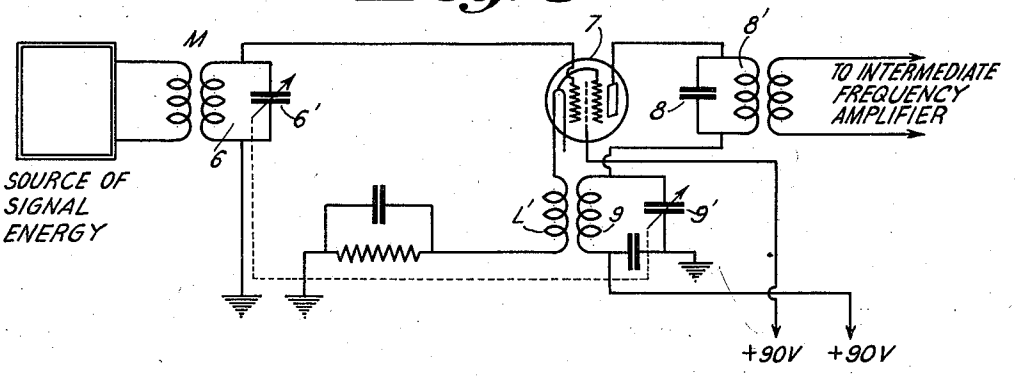
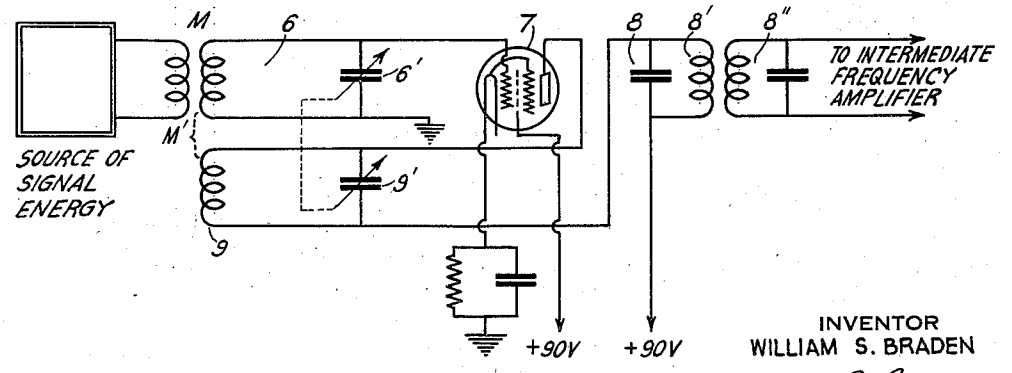


Fig. 4



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2,053,414

UNITED STATES PATENT OFFICE

2,053,414

HETERODYNE RECEIVING SYSTEM

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Application February 12, 1932, Serial No. 592,461

16 Claims. (Cl. 250—20)

My present invention generally relates to electrical systems for producing waves of high frequency, and more particularly pertains to methods of, and means for, receiving modulated high frequency waves.

As is well known the heterodyne method of reception consists in combining incoming high frequency currents with a locally generated current of a frequency which differs from that of the received current by an amount which may lie within the audible, or the super-audible, frequency range. The superheterodyne method of reception utilizes a beat, or intermediate, frequency which lies within the super-audible range, and in modern broadcast receivers a special tube is employed for producing the local oscillations.

Additionally, it has been proposed in the past to utilize a single tube and associated circuits, that is an autodyne method, for producing the local oscillations and heterodyning the signal currents with the locally generated currents to create the beat frequency currents. However, such combined local oscillator-frequency changer, or composite first detector-oscillator, arrangements have in the past been economical expedients rather than examples of improved technique. Such composite detector-oscillator arrangements have not, as far as operating performance is concerned, been comparable to superheterodyne receivers which utilized a special tube for producing the local oscillations.

Careful analysis of composite detector-oscillator circuits which have hitherto been proposed reveals the fact that one of the primary reasons of the relatively poor operation of this type of circuit resides in a particular type of distortion. It can be shown that when the incoming signal is applied to the control grid circuit of a composite detector-oscillator of the prior art, signals of intensity sufficient to swing the control grid highly positive are not faithfully reproduced in the output circuit of the composite arrangement. That is to say, and especially in the case of modern broadcast receivers of the superheterodyne type, such composite arrangements of the prior art are inherently incapable of detecting those components of a modulated carrier wave which correspond to the higher audio frequencies.

Accordingly, it is one of the principal objects of my present invention to provide a receiving system, operating according to the heterodyne method of reception, wherein modulated carrier waves are detected by means of a composite detector-oscillator which is so designed that its output comprises a faithful reproduction of the modulated carrier wave impressed upon its input.

Considering the abovementioned defect inherent in composite detector-oscillator circuits of the past, it can be shown that the electron discharge tubes which have been employed in such composite circuits were responsible for the inability of the composite detector to faithfully reproduce the modulated carrier wave received by it. I have found that the absence of control grid current is an essential condition for a composite detector-oscillator of great fidelity, when the incoming signal is applied to the control grid of the composite circuit.

Thus, it may be stated that it is an equally important object of the present invention to provide a radio receiver of the heterodyne type, and which receiver employs a composite detector-oscillator circuit, wherein the composite circuit utilizes an electron discharge tube possessing a dynamic characteristic such that the control grid of the tube is incapable of drawing current throughout the impression of signal voltages upon the said control grid.

In devising a superheterodyne receiver embodying the composite first detector-oscillator of the present invention, it has been found that the radio frequency oscillation circuit utilized in conjunction with the first detector circuit feeds back energy from the anode circuit thereof to its control grid circuit, and yet is easily adjusted to oscillate without causing control grid current to flow. In other words, the present invention, furthermore provides a method of, and means for, producing oscillations of radio frequency in a circuit employing a tube designed in such a manner that loading of the output circuit of the oscillator results in a dynamic characteristic whose upper bend, or saturation point, lies in the negative region of the control grid voltage swings.

The present invention, additionally, utilizes as a practical embodiment of the aforementioned dynamic characteristic, a circuit employing an electron discharge tube provided with five electrodes, a screen grid of positive potential commensurate with that of the anode potential being employed, and a shield grid, at cathode potential, being disposed between the anode and screen grid. Such a five-electrode tube, also referred to as a radio frequency pentode tube, possesses to a greater degree than is found in various other types of tubes, the latter usually of the triode and screen grid type, a pronounced third order effect in the characteristic relating control grid voltage to alternating current load voltage, and this third or-

characteristic lies within the negative region of grid potential values. Obviously, the use of an extremely high value of plate potential in connection with a tube constructed and designed to normally operate at a plate potential value far below the value represented in curve 1, is not only dangerous but results in an extremely small span of life for the tube.

Considering the dynamic characteristic A O B it will be observed that the upper saturation point also lies in the positive region of grid potential variation. Clearly, as the external plate resistance of the triode oscillation circuit is decreased the upper saturation point of the curve A O B will be merely shifted upwards, but will still lie within the positive region of grid potential values, while if the external plate resistance were increased the saturation point would be shifted downwards, but still lie within the aforesaid positive region. Hence, it will be observed that, whether considered from the dynamic or static viewpoint, the operating characteristic of a triode employed in an oscillation circuit, when normally operating potentials are used, possesses an upper saturation point lying within the positive region of grid potential values.

In order to clearly represent the effect of a dynamic characteristic, such as A O B, on a composite first detector-oscillator circuit, there is shown in the lower portion of Fig. 1 three groups of oscillations. The group designated as "Local oscillations" represents two cycles of local oscillation voltage variation produced in the output circuit of the composite detector-oscillator. Obviously, assuming a normal grid potential E_c located at point 0 on curve on curve A O B, the voltage swings of the locally generated oscillations should vary between a minimum negative value x, determined by the lower saturation point A, and a maximum positive value m_o, determined by the upper saturation point B.

Actually, however, the maximum positive swing of the locally generated voltage is found to be some value a_o less positive than the value m_o. This reduction of peak value, during the positive half of the locally generated voltage swing, is caused by the flow of grid current between the control grid and cathode of the oscillating triode. In other words, it will be seen that the locally generated voltage peaks are "cut-off" during the positive half of the voltage swings.

Consider, next, the group of oscillations designated as "Signal oscillations". It is assumed that there is impressed upon the control grid of the triode detector-oscillator signal voltage variations wherein the peaked values of maximum signal voltage are represented by the symbol p_s, and wherein a peak value of S_s represents the intensity of the wave form immediately adjacent each value p_s. The third group of oscillations is designated as "Intermediate frequency oscillations", and represents the resultant beat frequency voltage variations. In other words, the voltage variations of the third group of oscillations is the resultant produced in the output circuit of the composite detector-oscillator, the first two groups of oscillations mentioned above being heterodyned in accordance with the well known theory of heterodyne detection, the frequency of the beat voltage variations being the difference between the local oscillation frequency and the signal oscillation frequency.

Without attempting to shown any quantitative and exact relation between the three groups of oscillations shown in Fig. 1, from a qualitative view point it will be seen that, due to the reduction of positive peak value of locally generated voltages from m_o to a_o, there is produced a corresponding reduction at points along the intermediate frequency voltage swings corresponding to points p_s of the signal voltage swings. That is to say, if the positive half cycle represented by the symbol Y of intermediate frequency oscillations corresponds to the positive half cycle Y' of the signal oscillations, the peak value of the positive half cycle Y will be represented by the symbol p'_h instead of the value p''_h.

This decrease in intermediate frequency peak value at points of maximum intensity results because of the "cutting off" of the peaks at points m_o of the locally generated oscillations. This decrease in peak value of maximum intermediate frequency intensity points does not affect the adjacent value of intermediate frequency intensity S'_h. That is, the positive voltage swing at point S_s of the signal oscillation does not carry the control grid of the oscillating triode sufficiently positive to draw grid current, and hence the value S'_h is a faithful reproduction of the signal voltage value S_s impressed on the control grid.

However, it will be noted that the points of maximum signal intensity apparently appear to have the same intermediate frequency intensity as immediately adjacent points of lower signal intensity S_s. It will, therefore, be seen that the intermediate frequency output of the composite detector-oscillator will not faithfully reproduce the wave form impressed upon its input, as regards points of maximum signal intensity p_s. Thus, the fidelity of reproduction in a broadcast receiver of the superheterodyne type may be seriously impaired when a composite oscillator-detector employing a tube having static characteristics of the type shown by curves 2, 3, 4, and 5 is employed. It is repeated that the static characteristic represented by curve 1 cannot be considered since the plate potential represented by it is out of the question when considering a tube employing normal operating potentials far below those represented by curve 1.

From the aforegoing analysis it will be appreciated that the defect described in Fig. 1 can readily be eliminated by utilizing a tube which has a dynamic characteristic, the tube operating at normal potentials in the sense that conventional values are used, as shown in Fig. 1*a*. The tube whose dynamic characteristic is represented in Fig. 1*a* is a radio frequency pentode tube (such as the A—418), and possesses to a greater degree than is found in various other types of tubes a pronounced third order effect. This third order effect exists by virtue of normal pentode properties which may be employed safely, rather than by virtue of uncertain properties of a similar nature which are found in connection with other types of tubes. For example, the normal operating potentials of the type of tube represented in Fig. 1*a* includes 90 volts for the plate potential; 90 volts for the screen grid potential and —5 volts for the control grid bias.

It will be observed that the upper saturation point of the characteristic of this pentode tube lies within the negative region of the grid voltage values, whereas in Fig. 1 it was shown that it was not until excessively dangerous plate potentials were employed, that the upper saturation point was moved into the negative region of the grid potential variations. Obviously, when a tube having a dynamic characteristic of the type

shown in Fig. 1*a* is employed in a composite first detector-oscillator, the effect of grid current is absent, since the control grid can only be swung positive after the upper saturation point has been reached. The result is a simple radio frequency oscillator which employs feed-back from the plate circuit to the control grid circuit, and which is easily adjusted to oscillate without drawing grid current. The absence of grid current becomes the essential characteristic of the composite first detector-oscillator of the present invention when the incoming signal is applied to the control grid circuit.

In Fig. 2 there is shown a circuit arrangement wherein the source of signal energy is conventionally represented, the source being coupled, as at M, to the resonant input circuit of a pentode tube constructed to have the dynamic characteristic shown in Fig. 1*a*, the tube being represented by the numeral **7**. The input circuit **6** includes a shunt tuning condenser **6'**, the control grid of the tube being connected to the high potential side of the tuning condenser through a coil L_1. The anode of the pentode tube is connected to an energizing source supplying potential of 90 volts thereto, the anode being connected to its potential source through an anti-resonant network **8**, **8'** in series with a second anti-resonant network **9**, **9'**.

The network **8**, **8'** is maintained fixedly tuned to the desired intermediate frequency, the coil **8'** being coupled to a similar network **8''**, resonant to the intermediate frequency. It is to be understood that the network **8''** is connected to the input of a succeeding intermediate frequency amplifier. The amplifier may be followed by the usual remaining components of a superheterodyne receiver such as a second detector, an audio frequency amplifier, and some type of reproducer, these various components not being shown, since they are well known to those skilled in the art.

The resonant net-work **9**, **9'** is capable of being variably tuned by the tuning condenser **9'** to the local oscillation frequency, the frequency being of such a value at each setting that the difference between it and the signal frequency is equal to the desired intermediate frequency. For this purpose the condensers **9'** and **6'** are arranged for uni-control, as shown by the dotted line, and it is to be clearly understood that any arrangement and device well known to those skilled in the art may be employed for maintaining the frequency difference between the network **6** and network **9**, **9'** constantly equal to the desired intermediate frequency.

It is not necessary for the purpose of the present invention to go into such arrangements in detail, reference being made however to U. S. Patent No. 1,740,331 to W. L. Carlson. The coil **9** of the local oscillator circuit is magnetically coupled to the coil L_1, thus providing a means for permitting local oscillation potentials to be impressed upon the control grid of the pentode tube **7**. The fixed condenser **10** is connected in series between the low potential side of the condenser **9'** and the low potential terminal of the coil **9**, and functions as a by-pass condenser, and preferably has a value of 0.1 microfarad. It is to be noted that a point intermediate the condenser **10** and the variable condenser **9'** is grounded.

Bias for the control grid of the tube is secured by means of a resistor **11**, shunted by a condenser **12**, disposed in the grounded leg of the cathode of the tube, such a grid biasing arrangement being well known to those skilled in the art.

The screen grid electrode **13** is connected to a source of positive potential, and has preferably applied to it a potential of 90 volts, and may be connected to the same source to which the anode of the tube is connected. The shield grid **14** is disposed between the anode and screen grid **13**, the shield grid **14** being preferably connected within the tube to a point on the cathode which represents the average potential of the cathode. Further constructional details of this type of tube need not be given at this point. The manner in which a pentode tube is constructed is well known to those skilled in the art.

In Fig. 3 there is shown a modification of the arrangement shown in Fig. 2, the modification essentially consisting in coupling the coil **9** of the local oscillation circuit to the coil L', the latter being arranged in this case in the grounded leg of the cathode circuit instead of being disposed, as shown in Fig. 2, in series with the control grid. Otherwise, the circuit is exactly the same as shown in Fig. 2. It will be observed that in both the arrangements shown in Figs. 2 and 3, the coupling coil L is in the control grid circuit. It may be also stated at this point that the source of signal energy coupled to the network **6**, **6'** may be an antenna circuit, or even one, or more, stages of radio frequency amplification.

In Fig. 4 there is shown still another modification of the arrangements shown in Figs. 2 and 3. The arrangement in Fig. 4 is identical with those shown in Figs. 2 and 3 with the exception that the special coupling coil L is omitted, and, instead, the coil **9** of the local oscillation circuit is coupled magnetically, as at M', to the secondary coil in the tunable signal circuit **6**. Clearly, any other arrangement may be employed for feeding back energy from the output circuit of the pentode tube **7** to its input circuit in order to impress locally generated voltage upon the control grid of the pentode tube.

The reactions and interactions taking place in the composite first detector-oscillator employing the pentode tube **7**, and determining the dynamic characteristic shown in Fig. 1*a*, are so involved as to make desirable the use of mathematical formulae in elucidating the laws governing the phenomena taking place in the structure, and in particular in laying down rules of design whereby any one skilled in the art may construct the composite detector-oscillator of this invention.

Hence, consider the arrangements shown in Fig. 2 from the point of view of a simple amplifier wherein a signal at

$$\frac{\omega}{2\pi}$$

is applied across the coil L_1 in the control grid circuit of the pentode tube **7**, and in whose plate circuit there is disposed a tuned impedance

$$\frac{(\omega L)^2}{R}.$$

L is the value of inductance of the coil **9**, and R is the residual resistance of this coil which is to be understood as arranged in series therewith. Now, it can be shown that when a pentode tube of the type represented by tube **7** in Fig. 2 has plate and screen voltages applied to it of values such as 90 volts, and the load resistance

$$\frac{(\omega L)^2}{R}$$

is equal to substantially 50,000 ohms or more, the intercepts of the corresponding load line drawn on a family of I_p v. E_p characteristics for various

negative grid potentials show a characteristic relating plate current to control grid voltage as shown in Fig. 1*a*.

Employing B volts control grid bias, as shown in Fig. 1*a*, with a grid swing of A peak volts, the plate current, and hence the signal potential across the load

$$\frac{(\omega L)^2}{R},$$

may be closely represented by the following expression:

$$i = a\,A \sin \omega t - c(A \sin \omega t)^3.$$

Expanding the second term of the aforegoing expression, there is secured:

$$\tfrac{3}{4}cA^3 \sin \omega t - \tfrac{1}{4}cA^3 \sin 3\omega t.$$

Thus, it will be seen that the second term subtracts $\tfrac{3}{4}cA^3$ from aA as regards the plate current at

$$\frac{\omega}{2\pi}.$$

This subtractive quantity increases as the cube of the applied signal magnitude A, and, therefore, the potential across L (across the load resistance) may be considered as increasing with applied signal magnitude in a non-linear manner.

Designating μ_o as the amplification from grid circuit to load impedance, then μ_o is seen to depend upon the grid swing A, being the ordinate divided by the abscissa at any point P (considering potential across L plotted as ordinates against signal magnitude A as abscissae) corresponding to whatever particular value of A is involved. Obviously, if μ_o were plotted as ordinates against A as abscissae, then μ_o would decrease in a linear fashion with increasing values of A, and P would represent any point along this linear relation.

Now, remove the external source of signal across L_1, and obtain the signal potential across L_1 by coupling L_1 to coil 9, resulting in M_1, the phase being such that self-oscillation is possible. Let the oscillator potential in the grid circuit (and of course across L_1) be A and also let μ_o apply at A. Then, the amplification of A appearing across coil 9 is μ_oA, and the current through the coil 9 is

$$\frac{\mu_o A}{\omega L},$$

neglecting the very slight effect of the coil resistance R.

This current flows in M, and hence the potential across the mutual inductive reactance is

$$\frac{\mu_o A \omega M}{\omega L}.$$

This potential is A, at grid circuit potential. From this relationship there necessarily follows that:

$$\mu_o = \frac{L}{M}.$$

It then follows that the oscillation strength in the grid circuit of tube 7 will be automatically limited to a value whereat

$$\mu_o = \frac{L}{M}.$$

This value of A is fixed by designing L and M suitably. Thus, it is that there is secured in the arrangement shown in Fig. 2 a simple radio frequency pentode oscillator of the plate to grid feed-back type which is self-limited without grid current, and without plate current saturation as often employed in conjunction with grid current phenomena. It is also to be noted that the pentode oscillator of the present invention is unique in that the plate, screen and control grid voltages may well be normal in the sense that conventional values are used, resulting in normal high translation gain from radio frequency to intermediate frequency.

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 claims is:

1. In a composite detector-oscillator circuit an electron discharge tube provided with an input and an output circuit, means for resonating the input circuit to a desired signal frequency, means for resonating the output circuit to a desired local oscillation frequency, means for resonating a portion of the output circuit to a desired heterodyne frequency, the output and input circuits being coupled to produce local oscillations, and said tube having a dynamic signal grid voltage-plate current characteristic such that its upper saturation point lies in the negative region of signal grid voltage variation, said tube having its electrodes maintained at their normal operating potentials.

2. In a composite detector-oscillator circuit an electron discharge tube provided with an input and output circuit, means for resonating the input circuit to a desired signal frequency, means for resonating the output circuit to a desired local oscillation frequency, means for resonating a portion of the output circuit to a desired heterodyne frequency, the output and input circuits being coupled to produce local oscillations, and said tube having a dynamic signal grid voltage-plate current characteristic such that its upper saturation point lies in the negative region of signal grid voltage variation, said tube comprising a positive screen grid disposed between the control grid and anode, and a shield grid, at cathode potential, disposed between the screen grid and anode.

3. In a composite detector-oscillator circuit an electron discharge tube provided with an input and output circuits, means for resonating the input circuit to a desired signal frequency, means for resonating the output circuit to a desired local oscillation frequency, means for resonating a portion of the output circuit to a desired heterodyne frequency, the output and input circuits being coupled to produce local oscillations, and said tube having a dynamic signal grid voltage-plate current characteristic such that its upper saturation point lies in the negative region of signal grid voltage variation, said tube comprising a positive screen grid disposed between the control grid and anode, and a shield grid, at cathode potential, disposed between the screen grid and anode, the anode, screen grid and control grid being maintained at their normal operating potentials.

4. An oscillation circuit comprising an electron discharge tube provided with an input and output circuits, means for coupling the output and input circuits to produce oscillations, said tube being so constructed and designed as to possess a dynamic control grid voltage-plate current characteristic wherein its upper bend lies in the negative region of applied control grid voltages when the output

circuit is loaded, said tube comprising a pentode whose electrodes are maintained at their normal operating potentials.

5. In a superheterodyne receiver, a composite first detector-oscillator circuit including an electron discharge tube having a tuned input circuit and a loaded output circuit coupled to the input circuit, said tube including in addition to the usual cathode, control grid and anode at least one cold electrode so related to the other electrodes that the tube possesses a pronounced third order effect in its dynamic signal grid voltage-plate current characteristic at normal operating potentials whereby there is a complete absence of grid current when the peak value of incoming signal is applied to the input circuit of the tube.

6. In a superheterodyne receiver, a composite first detector-oscillator circuit including an electron discharge tube having a tuned input circuit and a loaded output circuit coupled to the input circuit, said tube being constructed to have a pronounced third order effect in its dynamic signal grid voltage-plate current characteristic whereby there is a complete absence of grid current when the incoming signal is applied to the input circuit of the tube, said tube comprising a pentode whose electrodes are maintained at their normal operating potentials.

7. An oscillator circuit comprising a pentode tube including in addition to a cathode, control grid and anode a screen grid, and a shield grid at cathode potential, said tube having an input circuit and a loaded anode output circuit, and means for feeding back energy from the output circuit to said input circuit.

8. In a superheterodyne receiver, a composite detector-oscillator circuit including a tube having a signal input network connected between the control grid and cathode, a network in the anode circuit of the tube resonant to a desired local oscillation frequency, means for regeneratively coupling the anode circuit and the signal input network, a network in the anode circuit resonant to the operating intermediate frequency, said tube including at least a positive cold electrode between the cathode and anode, and said tube being of the type having a dynamic control grid voltage—plate current characteristic such as to maintain the said grid at a negative potential with respect to the cathode throughout the swing of signal voltage applied to said input circuit whereby no grid current flows in the control grid circuit at the peaks of said swing.

9. In a superheterodyne receiver, a composite detector-oscillator circuit including a tube having a signal input network connected between the control grid and cathode, a network in the anode circuit of the tube resonant to a desired local oscillation frequency, means for regeneratively coupling the anode circuit and the signal input network through said cathode, a network in the anode circuit resonant to the operating intermediate frequency, said tube including at least a positive cold electrode between the cathode and anode, and said tube being of the type having a dynamic control grid voltage—plate current characteristic such as to maintain the said grid at a negative potential with respect to the cathode throughout the swing of signal voltage applied to said input circuit whereby no grid current flows in the control grid circuit at the peaks of said swing.

10. In a superheterodyne receiver, a composite detector-oscillator circuit including a tube having a signal input network connected between the control grid and cathode, a network in the anode circuit of the tube resonant to a desired local oscillation frequency, means for regeneratively coupling the anode circuit and the signal input network, a network in the anode circuit resonant to the operating intermediate frequency, said tube including at least a positive cold electrode between the cathode and anode, means for simultaneously tuning said signal and local oscillation networks through respective signal and oscillation frequency ranges, and said tube being of the type having a dynamic control grid voltage—plate current characteristic such as to maintain the said grid at a negative potential with respect to the cathode throughout the swing of signal voltage applied to said input circuit whereby no grid current flows in the control grid circuit at the peaks of said swing.

11. A high frequency circuit comprising a tube provided with a cathode, a signal control grid, an anode, and at least one cold grid electrode disposed between the cathode and anode, a signal input network connected between ground and said control grid, a connection from said cathode to ground including means for constantly maintaining the control grid negatively biased with respect to the cathode, a local oscillation network coupled between said cathode connection and one of the electrodes other than the cathode and control grid, and a connection from the anode to a network resonant to an intermedate frequency.

12. In a combined oscillator-detector network, a tube provided with a cathode, a signal grid, an anode, and at least a positive cold electrode between the control grid and anode, a signal input circuit connected between the cathode and signal grid, a coupling between the said input circuit and one of the cold electrodes of said tube other than said signal grid for producing local oscillations in said input circuit, a beat circuit connected to the anode of said tube, means for maintaining the said signal grid at a negative direct current potential with respect to said cathode, and the signal grid voltage-anode current characteristic of said tube being such that said signal grid is maintained at said negative potential even at substantially the peaks of the signal and local oscillation voltage swings.

13. In a combined oscillator-detector network, a tube provided with a cathode, a signal grid, an anode, and at least a positive cold electrode between the control grid and anode, a shield grid at cathode potential between said last electrode and the anode, a signal input circuit connected between the cathode and signal grid, a coupling between the said input circuit and one of the cold electrodes of said tube other than said signal grid for producing local oscillations in said input circuit, a beat circuit connected to the anode of said tube, means for maintaining the said signal grid at a negative direct current potential with respect to said cathode, and the signal grid voltage-anode current characteristic of said tube being such that said signal grid is maintained at said negative potential even at substantially the peaks of the signal and local oscillation voltage swings.

14. In a combined oscillator-detector network, a tube provided with a cathode, a signal grid, an anode, and at least a positive cold electrode between the control grid and anode, a signal input circuit connected between the cathode and signal grid, a coupling between the said input circuit

and one of the cold electrodes of said tube other than said signal grid for producing local oscillations in said input circuit, a beat circuit tuned to a super-audible frequency connected to the anode of said tube, means for maintaining the said signal grid at a negative direct current potential with respect to said cathode, and the signal grid voltage-anode current characteristic of said tube being such that said signal grid is maintained at said negative potential even at substantially the peaks of the signal and local oscillation voltage swings.

15. In a combined oscillator-detector network, a tube provided with a cathode, a signal grid, an anode, and at least a positive cold electrode between the control grid and anode, a signal input circuit connected between the cathode and signal grid, a coupling between the said input circuit and one of the cold electrodes of said tube other than said signal grid for producing local oscillations in said input circuit, a beat circuit connected to the anode of said tube, means in the cathode circuit of said tube for maintaining the said signal grid at a negative direct current potential with respect to said cathode, and the signal grid voltage-anode current characteristic of said tube being such that said signal grid is maintained at said negative potential even at substantially the peaks of the signal and local oscillation voltage swings.

16. In a combined oscillator-detector network, a tube provided with a cathode, a signal grid, an anode, and at least a positive cold screen electrode between the control grid and anode, a signal input circuit connected between the cathode and signal grid, a coupling between the said input circuit and one of the cold electrodes of said tube other than said signal grid for producing local oscillations in said input circuit, a beat circuit connected to the anode of said tube, means for maintaining the said signal grid at a negative direct current potential with respect to said cathode, and the dynamic signal grid voltage-anode current characteristic of said tube being such that said signal grid is maintained at said negative potential even at substantially the peaks of the signal and local oscillation voltage swings.

WILLIAM STODDARD BARDEN.