Aug. 16, 1932. G. RODWIN 1,871,741

CONSTANT BEAT FREQUENCY SYSTEM

Filed Jan. 30, 1929 2 Sheets-Sheet 1

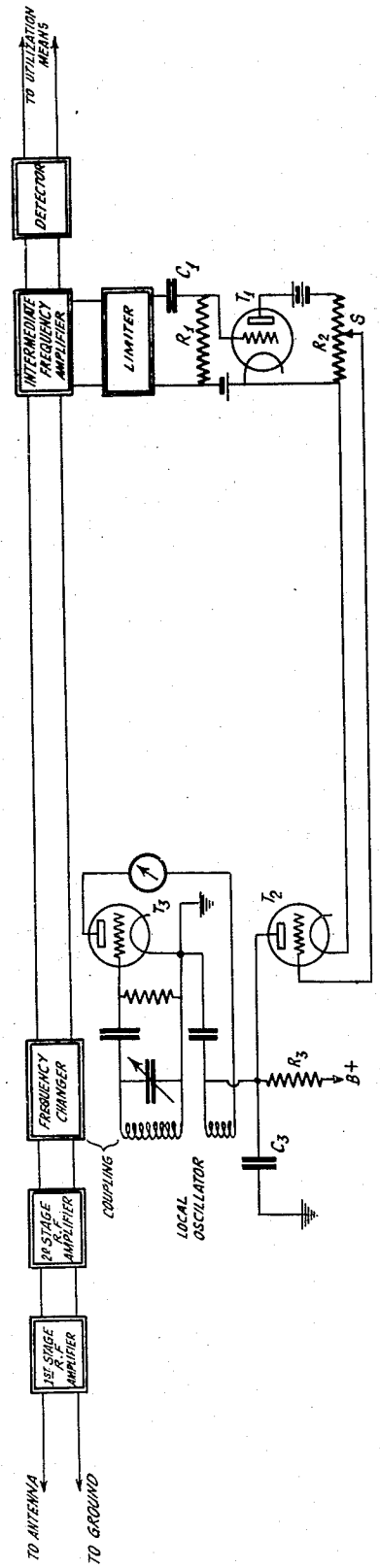


Fig. 1

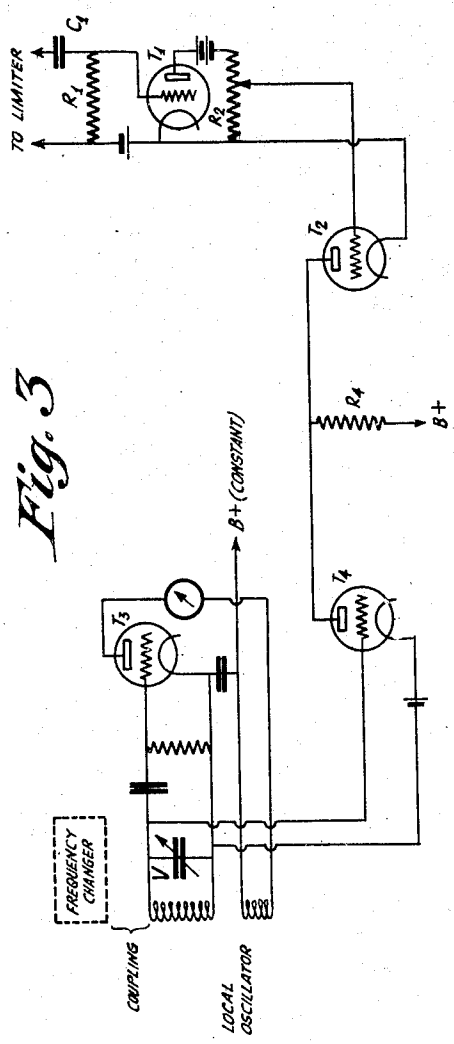


Fig. 3

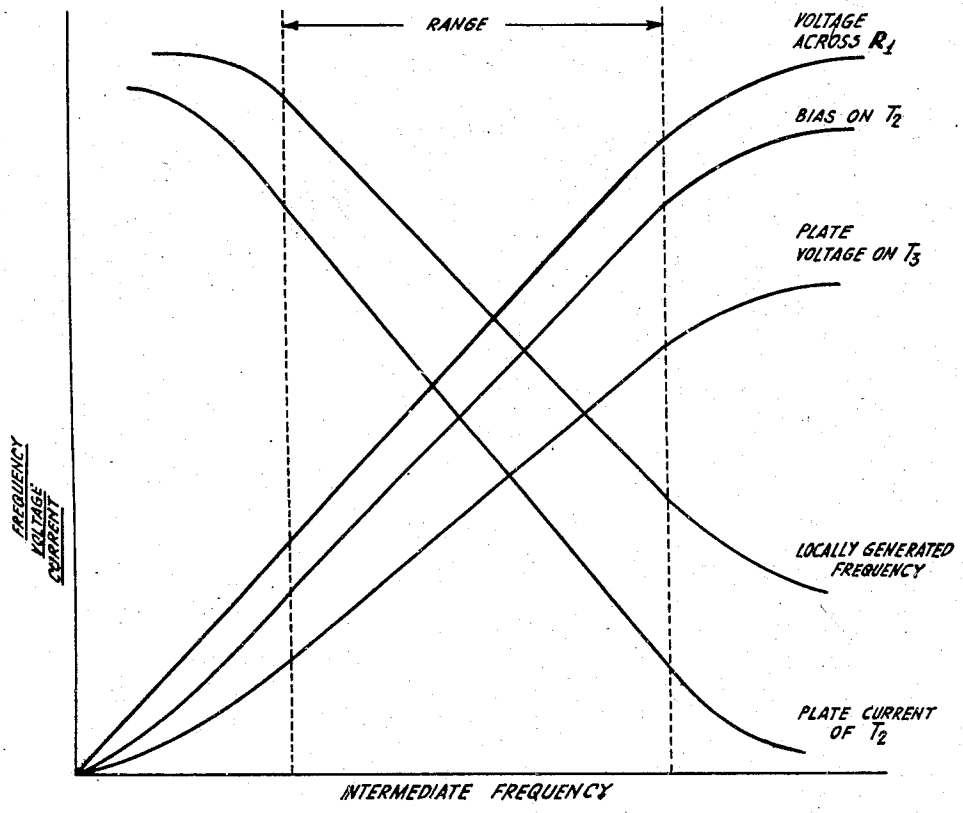
Inventor
GEORGE RODWIN

By his Attorney Ira J. Adams

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Fig. 2



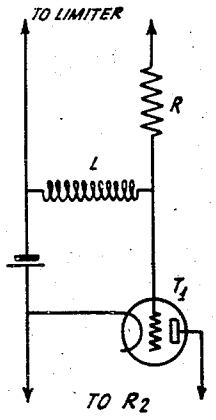


Fig. 4

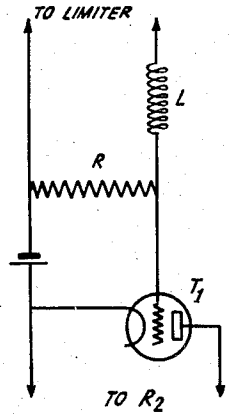


Fig. 5

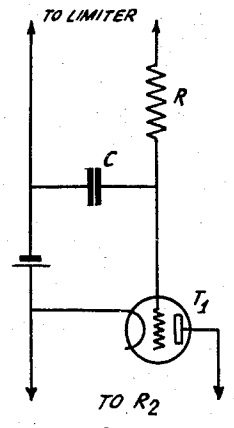


Fig. 6

Inventor
GEORGE RODWIN

By his Attorney Ira J. Adams

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UNITED STATES PATENT OFFICE

GEORGE RODWIN, OF NEW YORK, N. Y., ASSIGNOR TO RADIO CORPORATION OF AMERICA, A CORPORATION OF DELAWARE

CONSTANT BEAT FREQUENCY SYSTEM

Application filed January 30, 1929. Serial No. 336,089.

This invention relates to a system for controlling the local oscillator in a heterodyne circuit, and more particularly to a system for maintaining the locally generated frequency in a superheterodyne circuit at a definite fixed frequency relation with the frequency of the incoming signal.

It is often necessary, in reception of radio signals, to maintain a constant intermediate frequency in a superhetrodine receiver. This is especially difficult when the signal frequency is very high. What is usually done, in an attempt to maintain a constant intermediate frequency at the receiver, is to use oscillators, both at the transmitter and at the receiver, which are as constant as possible.

Crystal controlled oscillators are very often employed. When the necessary high degree of constancy is considered, it is easily appreciated that even crystal control oscillators cannot meet the requirements. It is understood, of course, that the difference in frequency between the crystals at the transmitter and receiver is equal to the intermediate frequency desired.

A small change in crystal frequency, when using short waves, may, therefore, result in a considerable change in intermediate frequency. By means of the system described and disclosed herein, it is possible to obtain a constant beat frequency at the receiver even when small variations of frequency are occurring in the transmitter or receiver, or both, and the said system has been found to be of special efficacy.

It is one of the main objects of my present invention, then, to provide a system for maintaining a beat frequency constant by utilizing variations in the said frequency to control the action of the local oscillator.

Another important object of the invention is to provide a method of maintaining the intermediate frequency constant in a superheterodyne circuit by transforming beat frequency variations into potential variations, and utilizing the said potential variations to control the action of the local frequency source in that direction which tends to maintain the intermediate frequency.

And still another object of the invention is to provide an intermediate frequency control in a superheterodyne receiving circuit, which control is adapted to maintain the intermediate frequency constant regardless of variations in signal frequency or local frequency, the control including a frequency differentiating circuit adapted to transform beat frequency variations into potential variations, means to amplify the potential variations, and means to utilize a portion of the amplified potential to control the source of local frequency in that direction which tends to maintain the intermediate frequency constant.

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.

The principle and certain applications of this invention are illustrated in the accompanying drawings, in which:

Fig. 1 is a schematic diagram showing the superheterodyne receiver embodying a circuit for controlling the locally generated intermediate frequency;

Fig. 2 is a graphic representation of the action of the control circuit shown in Fig. 1;

Fig. 3 is a modified form of the control circuit shown in Fig. 1;

Figs. 4, 5, and 6 are detailed views of three modified types of frequency differentiating circuits.

Referring more particularly to Fig. 1, there is shown a conventional superheterodyne receiver circuit, embodying two stages of radio frequency amplification coupled to a conventional frequency changer, the latter being coupled to a local oscillator in the well known manner. In its usual form, this frequency changer is a circuit employing an ordinary three electrode tube biased to operate on the lower curve portion of its plate current-grid voltage characteristic. Both

the incoming signal frequency and the locally generated frequency are applied to the grid of this tube. The difference frequency, or intermediate frequency, is taken out of the plate circuit thereof.

As is well known, the intermediate frequency is amplified by an intermediate frequency amplifier, the latter being coupled to a detector, which in turn is connected to utilization means of any type such as telephones, a loud speaker, and the like. The intermediate frequency amplifier is connected to a conventional limiting tube arrangement, and the output from the limiter is passed into a circuit connected to the local oscillator as shown. The circuit between the limiter and the local oscillator comprises two main elements, hereinafter termed respectively, the direct current amplifier tube, and the control tube.

The voltage from the intermediate frequency amplifier is fed into the limiter, and the output from the latter is passed into the subsequent frequency differentiating circuit connected thereto. The constants of capacity C_1, resistor R_1, and the frequency differentiating circuit, are such as to give a voltage across resistor R_1 which is variable with impressed frequency. Plate voltage for the control tube T_2 is taken through the same resistance R_3 as the plate supply to the local oscillator T_3. The constants of the oscillator circuit are such that its generated frequency varies inversely with the applied direct plate voltage.

Since it is desired to obtain a voltage variation across the resistance R_1 which is directly proportional to the intermediate frequency variation only, and is not affected by amplitude variation, the conventional limiting arrangement is disposed between the intermediate frequency amplifier and the circuit C_1, R_1. The limiter consists of an electron discharge tube connected to the intermediate amplifier so that for all values of input voltages from the amplifier, saturation is reached, whereby the limiter output is of constant amplitude, and can only vary in frequency. The limiter is conventionally shown to simplify the description, and since it is readily apparent to those skilled in the art that the particular type and arrangement used is unimportant, since any well known device adapted to perform the desired limiting function can be used.

In other words, as the plate voltage of oscillator tube T_3 goes up, the locally generated frequency f^2 goes down. It may be shown, both experimentally and mathematically, that the generated frequency of an oscillator may be varied in a small degree by a change in the applied plate voltage. As the plate voltage is increased, either an increase or decrease of frequency may occur, depending upon the circuit and tube characteristic. Reference to the December, 1928, issue of the Proceedings of the Institute of Radio Engineers, page 1719, will reveal a description of this phenomenon. The case described therein is a particular one, and considerable variations are obtainable.

I have chosen the circuit, in which the generated frequency decreases when an increase in plate voltage over the range of voltages is employed. For the circuit action to be carried through it is, therefore, necessary that the local oscillator frequency be higher than the frequency of the incoming signal. For example, assume that the desired intermediate frequency is 25,000 cycles and the incoming frequency f^1 is 12,500,000 cycles, then the local frequency f^2 would be 12,525,000 cycles. If, however, a local oscillator was employed in which the generated frequency increased with an increase in plate voltage, the local oscillator would have to be operated at a lower frequency than the incoming signal frequency.

If f^2 should tend to increase, the intermediate frequency would obviously increase, and due to the lessening of impedance offered by capacity C_1 to the increasing frequency, the alternating voltage across resistor R_1 will increase. T_1, the direct current amplifier tube, is normally operated at the lower bend of its plate current grid voltage characteristic. Accordingly, the plate current of tube T_1 will rise as the voltage across resistor R_1 increases.

The negative bias on the grid of T_2, the control tube, will increase, and the plate current of this tube will, therefore, decrease. There will now be less voltage drop across resistor R_3 and the plate voltage of the local oscillator T_3 will increase causing the generated frequency of oscillator T_3 to decrease. The adjustment of resistor R_2 is effected by the slider S, the latter being connected to the grid of tube T_2. The slider S is so positioned on resistor R_2 that the result of decrease in frequency of oscillator T_3, due to the increase in plate voltage of the latter, is just sufficient to compensate for the rise in frequency f^2 which initiated the increase in the plate voltage of oscillator T_3.

It is seen, therefore, that the intermediate frequency will be maintained constant. The purpose of capacity C_3 is to slow down the action of the circuit. If capacity C_3 were absent, the action would be almost instantaneous, and the locally generated frequency might then be influenced by the presence of either modulation on the incoming signal or fading. This condenser prevents the occurrence of rapid changes in voltage across resistor R_3 but does not prevent a slow change.

Fig. 2 graphically presents the operation described above. This figure shows, in a qualitative manner, the intermediate frequency plotted against voltage, current and

frequency. The abscissæ—intermediate frequency—are regarded as the "cause" of the action, and, the various ordinates—frequency, voltage and current—the "result". Thus, an attempted rise in intermediate frequency, due to the change in either the locally generated frequency f^2 or the incoming frequency f^1 will result in a decrease in the locally generated frequency.

It is to be noted that the rise in intermediate frequency, according to the curve shown in Fig. 2, results in an increase in voltage across resistance R_1; increase in the bias of control tube T_2; decrease of plate current of tube T_2; increase of plate voltage of oscillator T_3, and finally decrease of the locally generated frequency.

Another method of accomplishing the same result, which offers some advantages over the arrangement shown in Fig. 1, is disclosed in Fig. 3. For the sake of simplicity and brevity, the main members of the superheterodyne receiver are omitted, and only the control circuit is shown. Tube T_1 is connected to the limiter as in Fig. 1, the tube being connected through a resistance R_2 to a control tube T_2, as shown in Fig. 1.

In this case, however, the control tube is coupled to the local oscillator tube T_3 through an amplifier tube T_4. The input capacity of tube T_4, which is acting as a high frequency amplifier, is used to control the generated frequency of the local oscillator T_3. The input capacity of tube T_4 is shunted across the tuning condenser V of the circuit embodying T_3. Theoretically, it can be shown that the input capacity of the vacuum tube employed as an amplifier will vary with the impedance in its plate circuit.

The total resistance in the plate circuit of T_4 is made up of resistance R_4 and tube T_2 in parallel. The input capacity of tube T_4 can thus be varied by changing the plate impedance of tube T_2. The action of the remaining part of the circuit is the same as that of Fig. 1. Using the same nomenclature, when the local frequency f^2 increases the intermediate frequency will rise, and the drop across resistance R_1 will rise.

The negative bias on the grid of tube T_2 will then increase negatively, and the impedance of tube T_2 will rise. As a result, the input capacity of tube T_4 will rise, and, therefore, the generated frequency of the oscillator T_3 will be lowered. As before, the adjustment of resistance R_2 is made such that the lowering of the generated frequency of oscillator of T_3 is just equal to the rise of frequency which initiated the action of the control circuit. It is to be observed that any kind of load impedance may be substituted for resistance R_1, such as an inductance or tuned circuit. By adjusting the constants of the circuits, the action may be varied over a considerable range. It is also to be noted that in place of the frequency differentiating circuit C_1, R_1, shown in Figs. 1 and 3, numerous other arrangements may be used, as shown in Figs. 4, 5, and 6. In Fig. 4, for example, capacity C_1 is replaced by a resistance R, and the resistance R_1 is replaced by an inductance L.

When the frequency differentiating circuits shown in Figs. 5 and 6 are employed in place of capacity C_1 and resistance R_1 of Fig. 1, it is necessary to operate the local oscillator at the frequency f^2, lower than the incoming signal frequency f^1, since the available voltage on tube T_1 will now decrease with an increase of intermediate frequency.

The embodiments illustrated above have been shown by way of preference only. The appended claims should be construed as broadly as permissible since many and various changes may be made without departing from the scope of the invention as defined in the broader claims.

Having thus described my invention, what I claim and desire to secure by Letters Patent of the United States is:

1. A method of maintaining a local oscillator circuit including an electron discharge tube in a superhetrodyne receiving system at a definite, fixed frequency relation with the frequency of the incoming signal regardless of signal and local frequency variations which consists in limiting a portion of the heat frequency energy to remove amplitude variations therefrom, transforming the beat frequency variations into potential variations, amplifying the potential variations, and impressing a predetermined portion of the amplified potential upon the anode circuit of the tube.

2. A method of maintaining a constant intermediate frequency in a superheterodyne receiving system which consists in collecting signal energy, generating local oscillations with an electron discharge tube at a frequency different from the incoming signal energy by the intermediate frequency to be employed, limiting a portion of the intermediate frequency energy to remove amplitude variations, transforming intermediate frequency variations into potential variations, amplifying potential variations caused by intermediate frequency variations, and altering the potential of the anode of the tube with the amplified potential variations.

3. In the art of heterodyne reception, the steps of maintaining the beat frequency constant regardless of signal and/or local frequency variations which consist in limiting a portion of the beat frequency energy to remove amplitude variations therefrom, transforming the beat frequency variations into potential variations, amplifying potential variations caused by beat frequency variations, and controlling, with a predetermined portion of the amplified potential, the action

of the source of local frequency in such a manner as to maintain a certain definite fixed frequency relation between the local frequency and signal frequency.

4. A method of controlling the frequency of an oscillator tube in a superheterodyne receiving system so as to maintain a predetermined fixed relation between the local frequency and the signal frequency which consists in limiting a portion of the beat frequency energy to remove amplitude variations therefrom, transforming the beat frequency variations into potential variations, amplifying potential variations caused by variations in the difference frequency, biasing, with a portion of the amplified potential, the grid of a control tube whereby anode current flow of said control tube is varied, and finally varying, with the varying anode current, the anode potential of the oscillator tube.

5. In combination with a superheterodyne receiving circuit provided with an oscillator tube and an intermediate frequency amplifier, means coupled to said intermediate frequency amplifier for limiting a portion of the intermediate frequency energy to remove amplitude variations, means for transforming said intermediate frequency variations into potential variations, an amplifying tube coupled to the last named means, a control tube coupled to the output circuit of said amplifying tube, the output circuit of said control tube being connected to the output circuit of the oscillator tube of said superheterodyne circuit for varying the anode potential of the oscillator tube.

6. In combination with signal energy collecting means, a source of local oscillations of a frequency different from the frequency of the collected energy by a difference frequency to be detected, amplifying means for said difference frequency, means coupled to said difference frequency amplifier for limiting a portion of the difference frequency energy to remove amplitude variations, means for transforming said difference frequency variations into potential variations a second amplifying means coupled to said last named means, a control tube connected to a predetermined portion of the output circuit of said second amplifying means, the output circuit of said control tube being connected to the output circuit of said local source.

7. In the art of heterodyne reception, the steps of maintaining the beat frequency constant which consist in heterodyning incoming waves with a local frequency source, transforming beat frequency variations into potential variations after limiting a portion of said beat frequency energy to remove amplitude variations, amplifying the potential variations, and controlling, with a predetermined portion of the amplified potential, the action of the local frequency source in that direction which tends to maintain the beat frequency.

8. In the art of heterodyne reception, the steps of maintaining the beat frequency constant which consist in heterodyning incoming waves with a local frequency source, limiting a portion of the beat frequency energy to remove amplitude variations therefrom, thereafter transforming beat frequency variations into potential variations, amplifying the potential variations, and controlling, with a predetermined portion of the amplified potential, the source of local frequency so that its frequency is varied in that direction which tends to maintain the beat frequency constant.

9. In a radio receiving system, a receiving circuit, means including an electron discharge tube for heterodyning incoming waves, means for converting beat frequency variations into potential variations substantially free of amplitude variations, and means including an additional electron discharge tube responsive to said potential variations for varying the anode potential of the first tube on a change in frequency of either the incoming waves or the heterodyning means.

10. The method of receiving high frequency wave signals which consists in heterodyning the signals with a circuit including an electron discharge tube, transforming a variation in the beat current so produced, due to a change in the frequency of the waves, into potential variations free of amplitude variations, varying the potential of the anode of the tube with said potential variations, and causing such alteration in potential to vary the frequency of said circuit.

11. The method of receiving high frequency wave signals which consists in applying a heterodyne thereto from a local oscillator tube to produce a beat frequency, converting a change in the beat frequency to a potential change free of amplitude change, and altering the anode potential of the oscillator tube with said potential change.

12. In combination in a high frequency signalling system an oscillatory circuit including an electron discharge tube, means including a second electron discharge tube and associated circuits responsive to changes in the oscillator frequency and adapted to convert frequency variations into potential variations substantially free of amplitude variations, and a control tube connected between said frequency responsive means and the oscillatory circuit whereby said potential variations are caused to vary the potential of the control electrode of said control tube which controls the frequency of the oscillatory circuit.

13. In combination with a high frequency receiving system, means including an electron discharge tube for heterodyning incoming waves, means including an additional elec-

tron discharge tube responsive to beat frequency variations and adapted to convert the latter into amplified potential variations substantially free of amplitude variations, and control means including an electron discharge tube connected between the heterodyning and responsive means, whereby said amplified potential variations are caused to vary the conductivity of said control tube and thereby control the frequency of said heterodyning tube.

14. In a superheterodyne receiver, a source of amplified signal energy, a frequency changer circuit adapted to deliver energy at an intermediate frequency, a source of local oscillations comprising an electron discharge tube provided with a tunable input circuit coupled to said changer circuit and an output circuit, means for converting intermediate frequency variations into potential variations substantially free of amplitude variations, a control tube coupled to said converting means, the anode circuit of said control tube being connected to the anode circuit of said oscillator tube.

15. In a superheterodyne receiver, a source of amplified signal energy, a frequency changer circuit adapted to deliver energy at an intermediate frequency, a source of local oscillations comprising an electron discharge tube provided with a tunable input circuit coupled to said changer circuit and an output circuit, means for converting intermediate frequency variations into potential variations substantially free of amplitude variations, a control tube having its input circuit coupled to said converting means, an amplifier adjustably connected between said converting means and control tube, the anode circuit of said control tube being connected to the anode circuit of said oscillator tube.

GEORGE RODWIN.