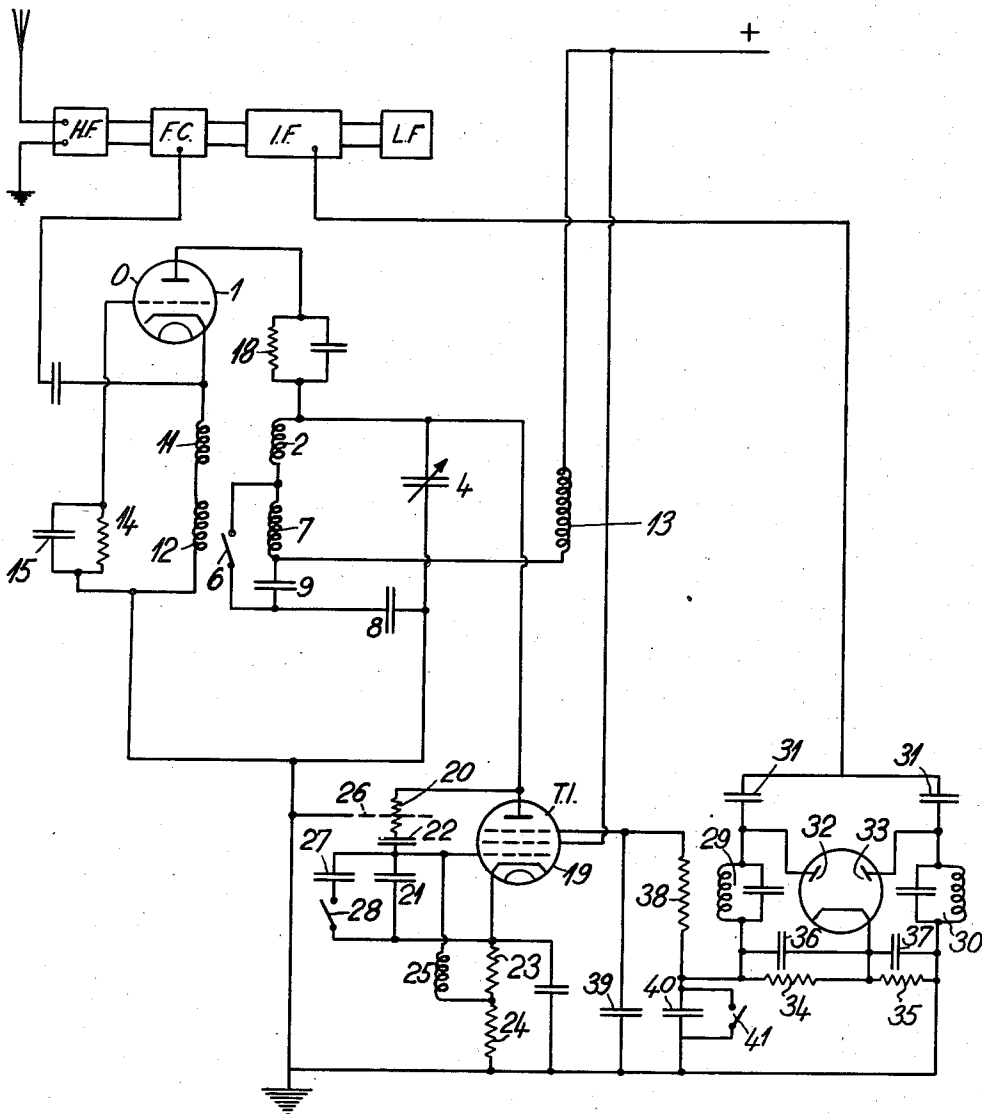


2,374,265

3 Sheets-Sheet 1



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April 24, 1945.

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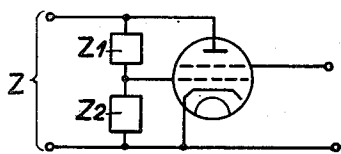


Fig. 2.

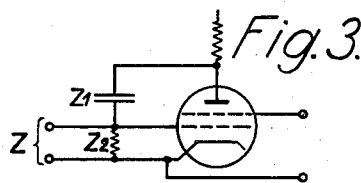


Fig. 3.

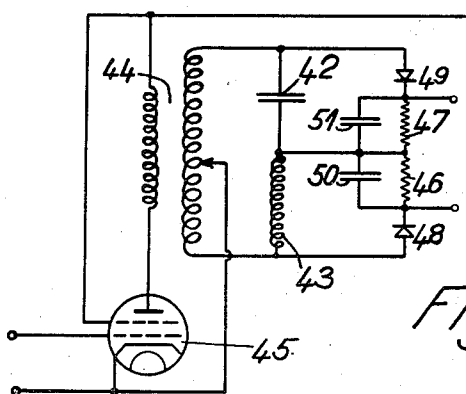


Fig. 4.

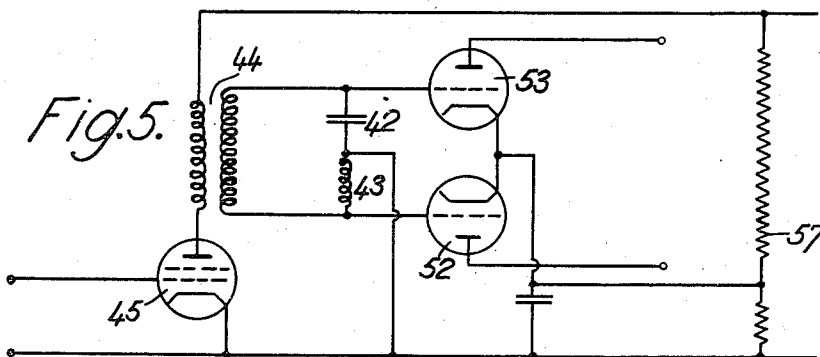


Fig. 5.

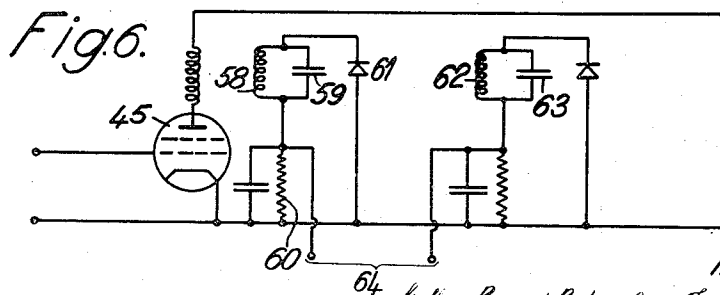


Fig. 6.

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Fig. 7.

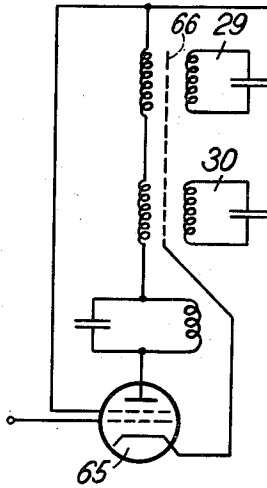


Fig. 9.

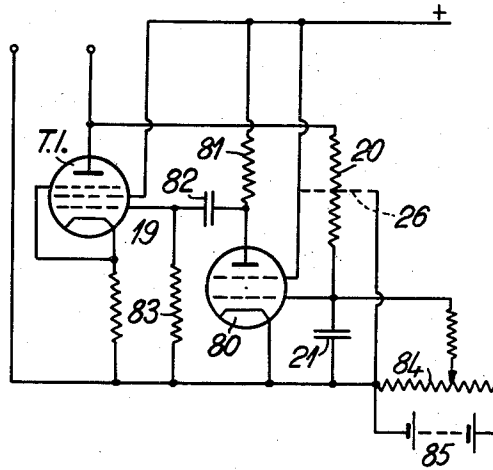
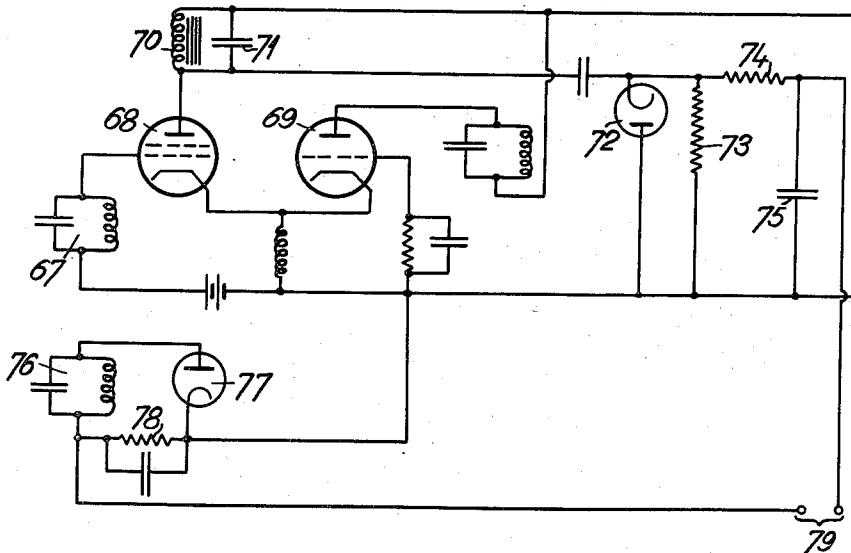


Fig. 8.



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TUNING OF RADIO RECEIVERS

Geoffrey Bernard Baker and George Frederick Hawkins, London, England, assignors to Murphy Radio Limited, London, England, a company of Great Britain

Application July 8, 1935, Serial No. 30,238
In Great Britain July 25, 1934

21 Claims. (Cl. 250—40)

Exact tuning of a radio receiver for signals conveyed by amplitude modulations of a carrier wave is a matter of some difficulty, both because it is difficult to perceive when the receiver is exactly tuned, more especially when it is equipped with automatic means of volume control, and because it is difficult to adjust the tuning means with great precision. Inexact tuning results in distortion.

The present invention is a superheterodyne radio receiver which when brought approximately into tune with an incoming signal will automatically adjust itself into nearly exact tune.

To this end the receiver includes an error detector which is brought into action by the approximate tuning of the receiver to an incoming signal, and a tune adjuster controlled by the error detector.

The error detector is in essence a circuit in which signals of different frequency produce responses of different magnitude and of different sign according as the signal frequency is above or below that to which the receiver is tuned. Signals with respect to which the receiver is so far out of tune that their reproduction is impaired, either by perceptible weakening or by perceptible distortion, must produce in it sufficient response to control the tune adjuster, so that tuning by hand accurate enough to satisfy a not very critical ear will bring the tune adjuster into action. The tune adjuster is essentially a means of tuning the receiver which is operated electrically, and must have a sufficient range to bring the receiver into tune with signals the reproduction of which would otherwise be perceptibly impaired.

There are various forms of error detector based, in general, upon the different response of one or more tuned circuits to signals of different frequency. In a single tuned oscillatory circuit consisting of inductance and capacity in series the difference between the peak voltage across the inductance and that across the capacity will vary in magnitude and sign as the frequency of an impulse applied to the circuit varies from a frequency below to a frequency above that to which the circuit is tuned, the voltages being equal when the impulse is in tune. Thus a series oscillatory circuit tuned to the intermediate frequency for which the superheterodyne receiver is designed and supplied with impulses from any of the intermediate frequency circuits of the receiver, will have across its inductance and capacity peak voltages which differ from each other except when the incoming signal produces in it signals of its natural frequency, that is to say except when the

local oscillator of the receiver is accurately tuned for the reception of the signal; if the local oscillator (tuned for example above the signal frequency) is of too high a frequency the impulses produced by heterodyning will be of higher than intermediate frequency, and the voltage across the capacity of the oscillatory circuit will be less than that across the inductance, and if the local oscillator is of too low a frequency the voltage across the capacity will exceed that across the inductance.

The voltage across an oscillatory circuit consisting of capacity and inductance in parallel will also vary in magnitude as the frequency of the applied impulse varies but will not change sign at exact tune. If, however, such a circuit is mistuned from the intermediate frequency and the voltage across it is balanced against a voltage independent of frequency and equal to that produced in the mistuned circuit by signals in tune with the receiver, the difference in the voltages will vary with the error and change sign as the error passes through zero.

Or if two oscillatory circuits sharply tuned the one to a frequency above and the other to a frequency equally far below the intermediate frequency of the receiver are supplied from one of the intermediate frequency circuits the voltages across them will differ except for impulses of the intermediate frequency, and the difference of the peak voltages will change sign at that frequency.

In order to employ for tuning adjustment voltages varying with tuning error obtained in any of these ways it is in general convenient to rectify them and where there are two to oppose the one to the other. Tuning in a superheterodyne receiver is effected mainly by varying the frequency of the local oscillator, a frequency which depends on the oscillatory circuit associated with the oscillating valve. To convert a voltage varying with the error in tuning into an adjustment of the parameters of an oscillatory circuit the invention employs as an impedance a passive thermionic valve network (i. e. one that is not self-oscillating) comprising a grid-controlled valve, an impedance connected between its anode and control grid, and a second impedance connected between the cathode and either the anode or the grid, the cathode forming one terminal of the impedance and the grid in the first case or the anode in the second case forming the other terminal. An element so formed may be made to present at the grid and cathode or anode and cathode terminals of the valve a reactance variable by variation of grid bias, or a resistance capable of reduction to

lower values by variation of grid bias than is the internal cathode-anode impedance of the valve; moreover the resistance so formed need not vary much on substitution of a valve since it depends on the slope of the valve which is reasonably constant from one to another.

In the first instance, namely by the inclusion of suitable impedance in its grid and anode circuits, those circuits being coupled together (whether by inductive or capacitative coupling or direct connection) the valve may be made to present, at its grid and cathode terminals, an effective impedance which may be of the nature of an inductance, a capacity, or a resistance according to the nature of the impedances employed; and the magnitude of the impedance thus presented may be varied by varying the potential on a control grid of the valve. For the effective impedance of the grid circuit of such a valve depends not only on the external impedance in the grid circuit, but also upon the impedance in the anode circuit and the slope of the valve (i. e. the rate of change of anode current with grid voltage); consequently with a given arrangement of external impedances the effective impedance between the grid and cathode terminals may be varied by varying the slope of the valve, which is done by varying the bias on a controlling grid, for example, in the case of a pentode, by varying the potential of the suppressor grid. If the effective impedance thus presented at the terminals is reactive it may be connected in parallel with the inductance or capacity associated with the local oscillator; if it is resistive it may be connected in series with an actual inductance or capacity across a part or the whole of the oscillatory circuit of the local oscillator.

A more convenient method of obtaining an effective impedance variable by varying an applied voltage, rests on the discovery that the effective impedance between the anode and cathode terminals of a high impedance valve may be made resistive or reactive by applying to its grid, by means of a potentiometer, a part of its anode voltage; and that the magnitude of the effective impedance varies with the slope of the valve. If an effective reactance is required the potentiometer must be made up of resistance and reactance so that the voltage applied to the grid is approximately in quadrature with the anode voltage. An effective reactance or effective resistance so constituted may be used as just described to tune an oscillatory circuit.

A valve used in any of these ways as an impedance is herein referred to as a thermionic impedance; a valve with impedance in its grid and anode circuits presenting at its grid and cathode terminals an effective impedance varying with the slope of the valve is referred to as a slope-controlled grid thermionic impedance; and a valve in which the grid voltage is determined in magnitude and phase relation to the anode voltage by means of a potentiometer so as to present an effective impedance at its anode and cathode terminals variable with slope is referred to as a slope-controlled anode thermionic impedance.

Typical embodiments of the invention are illustrated in the accompanying drawings.

Figure 1 shows a receiver employing oscillatory circuits tuned above and below intermediate frequency as the error detector and using the series opposed rectified voltages obtained from them to vary the suppressor grid potential of a pentode having a voltage approximately in quadrature

with its anode voltage applied to its grid by a potentiometer so that the valve acts as an inductance across the oscillatory circuit of the local oscillator.

Figure 2 is a more generalised form of the slope-controlled anode thermionic impedance employed in Figure 1.

Figure 3 is a slope-controlled grid thermionic impedance.

Figures 4, 5, 6 and 8 show alternative means of obtaining a voltage dependent upon the error in tuning and of employing it for varying the tune of an oscillator.

Figure 7 shows a further modification of Figure 1.

Figure 9 shows a modification of the slope-controlled anode impedance and a further application of it.

In Figure 1 those parts of the receiver not directly concerned in the invention are shown in the well-known diagrammatic block form. It is assumed that incoming signals are amplified in the high frequency amplifier HF, and heterodyned with oscillations generated by the local oscillator O and rectified in the frequency changer or first detector FC; the resulting impulses of intermediate frequency may be amplified in one or more stages in the intermediate frequency amplifier IF, and these are followed by a second detector and low frequency amplifier LF.

The oscillator O comprises, as usual, a triode having in its anode circuit an oscillatory circuit of variable frequency coupled with its grid circuit to generate oscillations. The oscillatory circuit comprises inductance 2 and variable capacity 4, to which may be added, by opening the switch 6, further inductance 7 and a fixed capacity 8, to adapt the receiver for the reception of a range of longer wave lengths. The amplitude of the oscillations generated is limited by the condenser-shunted resistance 18. The anode circuit is connected to the positive of the high tension supply through a choke 13. The grid circuit further includes a grid leak and condenser 14, 15.

It will be understood that the receiver is tuned by hand in the usual way by movement of the variable condenser 4. For the purpose of automatic adjustment of the tuning there is added to the oscillatory circuit 2, 4, 8, or 2, 4, 8, 9, 7 as the case may be, the equivalent of a further reactance consisting of the thermionic impedance TI. This is shown as a slope-controlled anode impedance made up of a pentode 19, the anode and cathode of which are connected across the oscillatory circuit of the oscillator, a potentiometer applying to the grid a part of the anode voltage which makes the valve behave as a reactance of the desired kind. As shown the potentiometer consists of a high resistance 20 of small capacity and a condenser 21, a blocking condenser 22 being interposed to enable their junction to be connected with the control grid of the pentode. The voltage applied to the grid by this potentiometer is approximately in quadrature with the anode voltage, and the valve presents at its anode and cathode terminals an effective impedance in the nature of an inductance. Condenser-shunted resistances 23 and 24 in the cathode circuit provide bias for the control and suppressor grids, the control grid bias being applied through the inductance 25 which may preferably be of such magnitude that with the condenser 21 it forms a circuit whose natural frequency lies below the range of wave lengths to be received.

The advantage of making this bias connection through an inductance is that the impedance of the now tuned portion of the grid circuit is increased at the low frequency end of each wave range, and the range of automatic tuning control is kept more nearly constant throughout the wave range.

It is important that the capacity of the resistance 20 should be small; it may be reduced by screening the ends from one another, as indicated diagrammatically by the earth-connected screen 26. The magnitude of the resistance itself will be less if the potentiometer 20, 21 is supplied from the oscillator anode circuit through a step-down transformer.

The anode circuit of the thermionic impedance may conveniently be supplied through the choke 13 and the inductance 2, 7 of the oscillator.

When by the opening of switch 6 the oscillator is suited for long wave lengths the effective inductance of the thermionic impedance should be correspondingly modified by adding to the condenser 21 a further condenser 27, which may be done by a switch 28 mechanically connected with the switch 6.

The effective inductance added by the thermionic impedance TI across the oscillatory circuit of the oscillator O may be varied by varying the potential of the suppressor grid of the pentode 19. This is done automatically by making the suppressor grid potential dependent on the extent to which the receiver is out of tune with the incoming signals to which it has been approximately tuned by hand. To this end oscillatory circuits 29 and 30 tuned to frequencies respectively above and below the intermediate frequency of the receiver are fed from one of the intermediate frequency circuits of the receiver through small condensers 31. Each of these oscillatory circuits 29, 30 supplies through a rectifier 32, 33 respectively, a load resistance 34, 35 and integrating condenser 36, 37, the two resistances being connected together. The rectifiers are here shown as diodes, and as combined into one bulb.

The resultant of the series opposed D. C. voltages produced across the resistance 34, 35 is applied to the suppressor grid of the pentode 19 through a decoupling resistance 38 with smoothing capacities 39, 40. A switch 41 which can be closed during tuning—for instance it may be operated by an initial pressure on the tuning knob required to free the knob so that it can be turned—short-circuits the resistances 34, 35 and puts the automatic control of the suppressor grid potential out of action. A sufficiently large condenser 39 and resistance 38 will delay the response of the tune corrector to prevent it acting during a merely momentary interruption of the hand tuning operation.

The action of the apparatus is as follows. During tuning by hand, when the switch 41 is closed, the receiver is not affected by the invention. When the switch 41 opens the voltage across the resistance 34, 35 is applied to the suppressor grid of the pentode 19. If the receiver is already exactly in tune this voltage will be zero, for the circuits 29 and 30 being equally out of tune, the one above and the other below the intermediate frequency, will have equal voltages across them. If the receiver is not in tune the impulses produced in the frequency changer FC and amplified in the intermediate frequency amplifier IF will not be exactly of intermediate frequency, but will be nearer to the frequency of one of the circuits

29, 30 than to that of the other. It will accordingly produce a greater response in that circuit; the voltages across the resistances 34 and 35 will then not be equal, and their difference will modify the suppressor grid voltage in the pentode 19 and so change the slope of the valve and modify the reactance of the thermionic impedance IF as a whole, thereby altering the frequency of the oscillator O in the direction requisite to bring the impulses produced by heterodyning more exactly to the intermediate frequency.

To obtain maximum effectiveness of tuning correction the difference in the natural frequencies of the two circuits 29, 30 should be equal to the band width of each. The requisite range of tuning correction depends on the selectivity of the receiver; it should extend on each side to such a degree of mistuning as would involve obvious distortion or reduction of volume, so that the user will not be satisfied with his tuning by hand until he has tuned into the range of automatic error correction.

The accuracy of calibration of the receiver as a whole will depend upon the tolerances in the design of the error detector and tuning correction circuits, as well as in the rest of the receiver; these, therefore, should be kept as small as possible. It will be noted, however, that excessive tolerance cannot lead to over-correction, which might be worse than the initial error in hand tuning; for the correcting voltage is itself reduced by the automatic tune correction.

It should be understood that the resistance-capacity potentiometer associated with the pentode 19 is an example only. In general if a potentiometer consisting of impedances Z_1 and Z_2 is connected as shown in Figure 2 between the anode and cathode of a valve, and its tapping is connected to the control grid, then the combination of valve and potentiometer will behave as an impedance Z of a value given approximately by

$$Z = \frac{Z_1 + Z_2}{1 + gZ_2}$$

where g is the slope of the valve, i. e.

$$g = \frac{\delta I_a}{\delta V_g}$$

I_a being the anode current and V_g the grid voltage. Or the valve itself may be said to behave as an impedance of a value

$$Z = \frac{Z_1 + Z_2}{gZ_2}$$

The value will be affected by the anode-cathode capacity of the valve which is assumed in the formula to be negligible, and also by the variation of anode current with anode potential which may be made negligible by the use of a screen grid valve. Z_1 and Z_2 may comprise any desired distribution of inductance, capacity and resistance, and instead of being directly connected the grid and anode circuits may be otherwise coupled. Also the grid fraction of the anode voltage determined by the potentiometer may be amplified before it is applied to the grid, as hereinafter explained with reference to Figure 9.

As already noted in reference to 20, 21 of Figure 1, if Z_1 is a resistance R and Z_2 a capacity C the impedance Z is an inductance approximately of the value

$$L = \frac{RC}{g}$$

and of phase angle—

$$\phi = \tan^{-1} \omega RC$$

If, instead, Z_1 and Z_2 are such that the grid and anode voltages are in phase, Z is purely resistive. In that case no variation of frequency would result from connecting it directly across the oscillatory circuit of T1 as in Figure 1 but it will control frequency if connected across that circuit in series with a reactance. A thermionic valve without a potentiometer or external impedances may similarly be used as a resistance variable by variation of the grid bias. But a valve used as a variable resistance in series with an impedance will not give a wide range of tuning on all wave lengths. To remedy this the reactance in series with the valve may itself be variable; for instance it may be a condenser ganged with the tuning condenser 4. Or the reactance in series with the valve may be a condenser in series with a choke, so that the effective capacity is increased at the low frequency end of the wave range.

It is also possible to use the grid and cathode terminals of a valve with external coupled or connected impedances as a variable impedance as indicated in Figure 3.

To the cathode and suppressor grid terminals is applied the voltage obtained from the error detector, which varies the slope of the valve and so varies the impedance between the control grid and cathode terminals, which are connected across the oscillatory circuit to be tuned, directly if the impedance is reactive, or in series with a reactance if the impedance is resistive.

These methods of tuning by varying the grid voltage of a valve are particularly adapted for tuning at a distance. Where, therefore, remote control is desired, for instance in a receiver carried upon a motor car, the initial tuning of the receiver by hand may be carried out in this way, the control handle merely varying, for instance by means of a potentiometer, the voltage applied to a grid of the valve of a thermionic impedance in the circuit to be tuned. This is illustrated in Figure 9. It will be understood that the anode and cathode of the thermionic reactance T1 are connected as in Figure 1 across the oscillatory circuit to be tuned. As in Figure 1 also, there is a potentiometer consisting of resistance 20 and capacity 21 connected between anode and cathode. Their junction may be connected to the control grid of the pentode 19 as in Figure 1; as shown, however, to give increased effect the voltage across the capacity 21 is amplified before application to the pentode grid. For this purpose the junction of 20 and 21 is joined to the control grid of an amplifying valve 80 the anode of which has resistance capacity coupling 81, 82, 83 with the control grid of the pentode 19. The magnitude of the thermionic reactance so formed may be controlled by varying the voltage on the suppressor grid of the pentode as in Figure 1, or as shown in Figure 9 by varying the slope of the valve 80, for which purpose its control grid is connected with a potentiometer 84 at the remote control point bridged across a source of voltage 85; the tapping point of the potentiometer is adjustable by the tuning knob. Or the slope of both valves 19 and 80 may be thus controlled.

The effective impedance of a thermionic anode impedance with amplified slope control as shown in Figure 9 is

$$Z = \frac{Z_1 + Z_2}{1 + mgZ_2}$$

where m is the amplification of the valve 80; in

other words the pentode 19 in these circumstances presents an effective impedance

$$Z_e = \frac{Z_1 + Z_2}{mgZ_2}$$

It is important that there should be no coupling between the two tuned circuits 29, 30 of frequencies respectively above and below the intermediate frequency employed for error detection. Figure 1 shows them fed through very small condensers 31. They could instead be fed through high resistances. Or they may be transformer fed, as shown in Figure 7, from the anode circuit of an intermediate frequency amplifying valve 65, an earthed screen 66 being placed between the windings to minimise the coupling.

Other ways of obtaining a voltage dependent on the error in tuning, for the purpose of tuning an oscillatory circuit, either by biasing a valve grid as above described or by other means, are illustrated in Figures 4, 5 and 6. Figure 4 makes use of a single tuned circuit consisting of capacity 42 and inductance 43 in series. The circuit is fed through transformer 44 from an intermediate frequency amplifying valve 45. Across the inductance and across the condenser are connected load resistances 46, 47 in series with rectifiers 48, 49 and shunted by integrating condensers 50, 51. The rectified voltages arising across 46 and 47 are used as in Figure 1, or as in the modifications of that scheme illustrated in Figures 2 and 3.

The rectifiers 48, 49 may be diodes as in Figure 1, or metal oxide rectifiers as indicated, or they may be triodes working on the bend of their grid volts-anode current characteristic in which case they will serve for amplification also and the circuit becomes that of Figure 5. The grid bias of the valves 52, 53, shown in Figure 5 as obtained from a potentiometer 57, may alternatively be obtained in any usual way, for instance from a resistance in the cathode circuit, or from a battery.

Figure 6 also makes use of a single tuned circuit, but in this case its inductance 58 and condenser 59 are in parallel, and the circuit is tuned not to the intermediate frequency but to a frequency differing from it by a suitable amount. This circuit is inductively fed from an intermediate frequency amplifying valve 45 and its response is rectified by any suitable rectifier 61 and sets up a D. C. voltage across the load resistance 60. But its response will not be zero when the receiver is exactly tuned.

Unless the receiver has perfect automatic volume control, the response of the circuit 58, 59 will depend not only on the frequency but also on the amplitude of the received signals. To compensate for such variations of amplitude the voltage produced by the circuit 58, 59 should be balanced against the voltage produced by another circuit 62, 63 tuned to the intermediate frequency, similarly supplied from an intermediate frequency circuit of the receiver, and similarly equipped with a rectifier. The difference between the rectified voltages will appear at the terminals 64, which will be connected to a galvanometer or into the grid circuit of the valve of a thermionic impedance as already explained.

Yet another method of obtaining a voltage for tune correction purposes dependent on the extent of the error in tuning is to employ an amplifying circuit in which amplification is proportional to frequency. This is illustrated in Figure 8. From an intermediate frequency circuit 67 of the receiver voltage is supplied to a frequency changer 68 where it is heterodyned

with the output of a local oscillator 69. This produces modulation at a lower frequency in the anode circuit of 68 which contains a choke 70 with a condenser 71 to by-pass the high frequency component of the current. The effect of the choke is to make the amplification of 68 depend on the frequency, and so its output, rectified by a diode or the like 72, will provide across the resistance 73 a voltage varying with the error in tuning, which can be applied through a de-coupling resistance 74 and condenser 75 in any of the ways heretofore described. But this rectifier voltage will also vary with the amplitude of the received signal unless the input to the frequency changer 68 is rendered constant by automatic volume control. To compensate for variations of signal amplitude the rectified output of the frequency changer is balanced against the rectified output of another circuit 76 tuned to the intermediate frequency and fed from an intermediate frequency circuit, and equipped with a rectifier 77 and load resistance 78. The difference in the two voltages which should vary with the error in tuning alone is available at the terminals 79 and may be used as above described.

It will be appreciated that in general any of the error detectors above described may be combined with any of the tune correcting means, but not all combinations are convenient; for example where the correcting voltage is produced between points neither of which is at earth potential it cannot readily be employed as bias between the grid and cathode of a valve, unless a separate high tension supply is provided for the valve to be so biased.

Also the characteristic of the error detector, that is to say the volts produced per kilocycle error in tuning, and the characteristic of the tune corrector, that is to say the kilocycles correction produced per volt applied to the corrector, should be adapted to each other so that the remanent error is a small fraction of any initial error in hand tuning within the range of correction desired.

We claim:

1. An electrically tunable oscillator comprising a thermionic valve with coupled grid and anode circuits, one of them oscillatory, a shunt bridged across said oscillatory circuit, a second thermionic valve containing at least one control grid and having its anode-cathode circuit included in said shunt, a potentiometer bridged across the anode and cathode of said second valve and having a tapping connected to the control grid of said valve, and means for varying the bias on a grid of said second valve.

2. An electrically tunable oscillator comprising a thermionic valve with coupled grid and anode circuits, one of these oscillatory, said oscillatory circuit including the anode-cathode circuit of a second thermionic valve containing at least one control grid and having a high resistance connected between its anode and control grid and a capacity connected between its control grid and cathode, and means for varying the bias on a grid of said second valve.

3. An electrically tunable oscillator comprising a thermionic valve with coupled grid and anode circuits, one of them oscillatory, said oscillatory circuit including the anode-cathode circuit of a pentode having a high resistance connected between its anode and control grid and a capacity connected between its control grid and cathode, and means for applying a variable potential to the suppressor grid of said pentode.

4. In a superheterodyne radio receiver provided with a frequency changer, the combination of a local oscillator comprising a thermionic valve with coupled grid and anode circuits, one of them oscillatory, said oscillatory circuit including the anode-cathode circuit of a second thermionic valve having at least one control grid and having a high resistance connected between its anode and control grid and a capacity connected between its control grid and cathode, an inductance connected with said control grid forming with said capacity a circuit of natural frequency outside the range of wave lengths of the oscillator, and means for applying a bias to said control grid through said inductance, with means for applying to a grid of said second valve a bias varying with the frequency of the output of said frequency changer to vary the reactance of the anode-cathode circuit.

5. In a superheterodyne radio receiver having a frequency changer, a local oscillator including a thermionic valve with coupled grid and anode circuits one of which is oscillatory and tunable, and means for feeding to said frequency changer received signals and oscillations generated by said oscillator, the combination with said local oscillator comprising a second thermionic valve having its anode-cathode circuit bridged across the oscillatory circuit of said oscillator, a potentiometer including resistance and reactance bridged across the anode and cathode of said second valve with a tapping connected to the control grid of said second valve, and means for applying to a grid of said second valve a bias varying with the frequency of the output of said frequency changer to vary the reactance of the anode-cathode circuit.

6. In a superheterodyne radio receiver having a frequency changer, a local oscillator having a tunable circuit for varying the frequency of oscillations generated, means for feeding received signals and the oscillations generated by said oscillator to said frequency changer to heterodyne them, circuits fed from said frequency changer tuned to an intermediate frequency, two oscillatory detector circuits one tuned to frequencies above and the other tuned to frequencies below said intermediate frequency, and means for feeding said tuned detector circuits from an intermediate frequency circuit, the combination with the tunable circuit of said oscillator comprising a pentode provided with an anode, cathode, grid, control grid and a suppressor grid, said pentode having an anode-cathode circuit included in said tunable circuit, a high resistance connected between the anode and control grid of said pentode, a capacity connected between the control grid and cathode of said pentode, means for rectifying and opposing to each other voltages produced in the tuned detector circuits of said receiver, and means for applying the difference of said voltages to the suppressor grid of said pentode.

7. In a superheterodyne radio receiver, an electrically tunable oscillator comprising a thermionic valve with coupled grid and anode circuits one of which is oscillatory, said oscillatory circuit including the anode-cathode circuit of a second thermionic valve having at least one control grid and having a high resistance connected between its anode and control grid and a capacity connected between its control grid and cathode, an inductance connected with said control grid and forming with said capacity a circuit of natural frequency below the range of wave lengths of the

oscillator, and means for varying the bias on a grid of said second valve.

8. In a superheterodyne radio receiver, an electrically tunable oscillator comprising a thermionic valve with coupled grid and anode circuits one of which is oscillatory, said oscillatory circuit including the anode-cathode circuit of a pentode having an anode, cathode, grid, control grid and suppressor grid, a high resistance connected between the anode and control grid of said pentode, a capacity connected between said control grid and the cathode of said pentode, an inductance connected with said control grid and forming with said capacity a circuit of natural frequency below the range of wave lengths of the oscillator, and means for applying a variable potential to said suppressor grid.

9. In a superheterodyne radio receiver, an electrically tunable oscillator comprising a thermionic valve with coupled grid and anode circuits one of which is oscillatory, said oscillatory circuit including the anode-cathode circuit of a pentode having an anode, cathode, grid, control grid and suppressor grid, a high resistance connected between the anode and control grid of said pentode, a capacity connected between said control grid and the cathode of said pentode, condenser-shunted resistances in the cathode circuit of said pentode providing bias for the control and suppressor grids, and an inductance connected between said resistances and said control grid, said inductance forming with the condenser, connected between the anode and control grid, a circuit of natural frequency lying below the range of wave lengths of the oscillator.

10. In a superheterodyne radio receiver, an electrically tunable oscillator comprising a thermionic valve with coupled grid and anode circuits one of which is oscillatory, said oscillatory circuit including the anode-cathode circuit of a pentode having an anode, cathode, grid, control grid and suppressor grid, a high resistance connected between the anode and control grid of said pentode, a capacity connected between said control grid and the cathode of said pentode, condenser-shunted resistances in the cathode circuit of said pentode providing bias for the control and suppressor grids, an inductance connected between said resistances and said control grid, said inductance forming with the condenser, connected between the anode and control grid, a circuit of natural frequency lying below the range of wave lengths of the oscillator, and means for applying a corrective potential to said suppressor grid.

11. In a superheterodyne radio receiver, an electrically tunable oscillator comprising a thermionic valve with coupled grid and anode circuits one of which is oscillatory, said oscillatory circuit including the anode-cathode circuit of a pentode having an anode, cathode, grid, control grid and suppressor grid, a high resistance connected between the anode and control grid of said pentode, a capacity connected between said control grid and the cathode of said pentode, condenser-shunted resistances in the cathode circuit of said pentode providing bias for the control and suppressor grids, an inductance connected between said resistances and said control grid, said inductance forming with the condenser, connected between the anode and control grid, a circuit of natural frequency lying below the range of wave lengths of the oscillator, and means for applying to said suppressor grid a potential

dependent upon the error in tuning said oscillator.

12. In a superheterodyne radio receiver, a local oscillator comprising a thermionic valve with coupled grid and anode circuits one of which is oscillatory, said oscillatory circuit including the anode-cathode circuit of a second thermionic valve having a high resistance connected between its anode and control grid and a capacity connected between its control grid and cathode, and means for applying to a grid of said valve a potential responsive to the mistuning of said oscillator.

13. In a superheterodyne radio receiver, a local oscillator comprising a thermionic valve with coupled grid and anode circuits, one of which is oscillatory, a pentode having an anode, cathode, grid, control grid and suppressor grid, the oscillatory circuits including the anode-cathode circuit of said pentode, high resistance connected between the anode and control grid of said pentode, a capacity connected between the control grid and cathode of said pentode, and means for applying to said suppressor grid a potential responsive to the mistuning of said oscillator.

14. A modulated carrier wave receiver comprising tuning control means, discriminating means for developing a potential difference which in its sign and magnitude, is dependent upon the sense and magnitude of the mistuning of said receiver with respect to a desired carrier, a thermionic valve having a cathode, an anode and two control grids arranged to control the space current in said valve in succession, means for establishing said potential difference between one of said control grids and said cathode, a connection including a condenser between the anode and the other control grid, means for causing the effective reactive impedance between the other of said control grids and said cathode to control the tuning of at least a part of said receiver, and compensating means for varying the magnitude of said effective reactive impedance corresponding to a fixed amount of mistuning in accordance with the frequency of said desired carrier so that pull-in tuning of substantially constant effectiveness is obtained at all frequencies within a pre-determined range.

15. A superheterodyne receiver comprising a frequency changer network including a tunable local oscillator circuit, an intermediate frequency network, means for demodulating the intermediate frequency energy, a discriminator network, connected to the intermediate network, to have intermediate frequency energy impressed thereon, constructed and arranged to produce a direct current voltage whose magnitude is solely dependent upon the frequency of said impressed energy, an electron discharge tube including at least an output electrode and a pair of input electrodes and having its output electrode connected to the oscillator circuit, an impedance coupled to the oscillator circuit across which is developed an alternating voltage substantially in quadrature with the output electrode alternating potential of said electron discharge tube, means for impressing said last voltage upon the input electrodes of said tube, and means for impressing the direct current voltage produced by said discriminator upon an input electrode of said tube whereby the frequency of said local oscillator circuit may be adjusted in a predetermined direction, and said impedance being a condenser whereby said tube reflects a negative inductance across the oscillator circuit.

16. In combination with an electron discharge tube having input and output circuits reactively coupled to produce oscillations, at least one of the coupled circuits being resonant to a desired oscillation frequency, means for adjusting the frequency of the resonant circuit comprising a tube having at least an input electrode and an output electrode, means feeding alternating potential from the second tube output electrode to a point of relatively high potential of said resonant circuit, means for impressing upon said input electrode alternating voltage derived from the oscillation tube which is in phase quadrature with said potential, and means for controlling the gain of said second tube, said impressing means including a reactance in the space current path of the oscillation tube.

17. In combination with an electron discharge tube having input and output circuits reactively coupled to produce oscillations, at least one of the coupled circuits being resonant to a desired oscillation frequency, means for adjusting the frequency of the resonant circuit comprising a tube having at least an input electrode and an output electrode, means feeding alternating potential from the second tube output electrode to a point of relatively high potential of said resonant circuit, means for impressing upon said input electrode alternating voltage derived from the oscillation tube which is in phase quadrature with said alternating potential, and means for controlling the gain of said second tube.

18. An electrically tunable oscillator comprising a thermionic valve with coupled grid and anode circuits, one of them oscillatory, a second thermionic valve containing at least one control grid and having its anode-cathode circuit included in said oscillatory circuit, means for applying to said control grid of said second valve a fraction of the alternating component of its anode-cathode voltage, and means for varying the gain of said second valve.

19. An electrically tunable oscillator comprising a thermionic valve with coupled grid and anode circuits one of them oscillatory, a thermionic reactance associated with said oscillatory circuit to form a tunable element thereof, said thermionic reactance comprising a second thermionic valve having at least one control grid with means for applying to its grid a fraction of its anode voltage approximately in quadrature with its anode voltage, and means for varying the gain of said second valve and thereby varying the reactance of said thermionic reactance.

20. In combination with an electron discharge tube having input and output circuits reactively coupled to produce oscillations, one of said circuits being oscillatory, means constituting a variable component reactance of said oscillatory circuit, said means comprising a tube circuit including at least one tube and having input and output electrodes, means feeding alternating voltage from the output electrodes of said tube circuit into said oscillatory circuit, means for impressing upon the input electrodes of said tube circuit alternating voltage derived from the oscillation tube which is in phase quadrature with the alternating voltage fed from the output electrodes of said tube circuit, and means for varying the gain of said tube circuit.

21. An electrically tunable oscillator comprising a thermionic valve with coupled grid and anode circuits, one of them oscillatory, a second thermionic valve containing at least one control grid and having its anode-cathode circuit effectively connected across said oscillatory circuit, means for applying to said control grid of said second valve a fraction of the alternating component of its anode-cathode voltage, and means for varying the gain of said second valve.

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