Nov. 26, 1935. H. A. WHEELER 2,022,068

RADIORECEIVER

Filed Dec. 14, 1931

Fig. 1

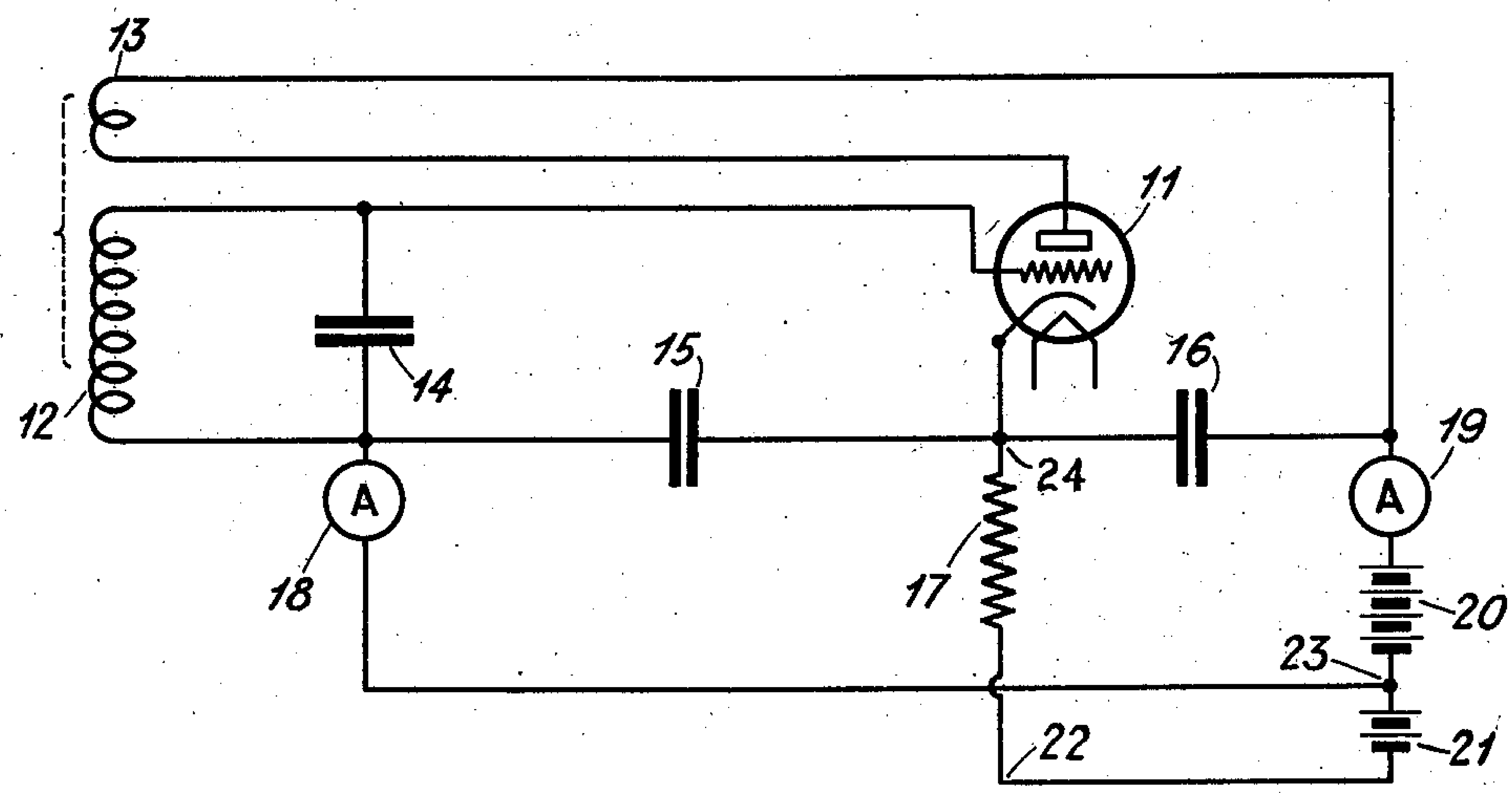
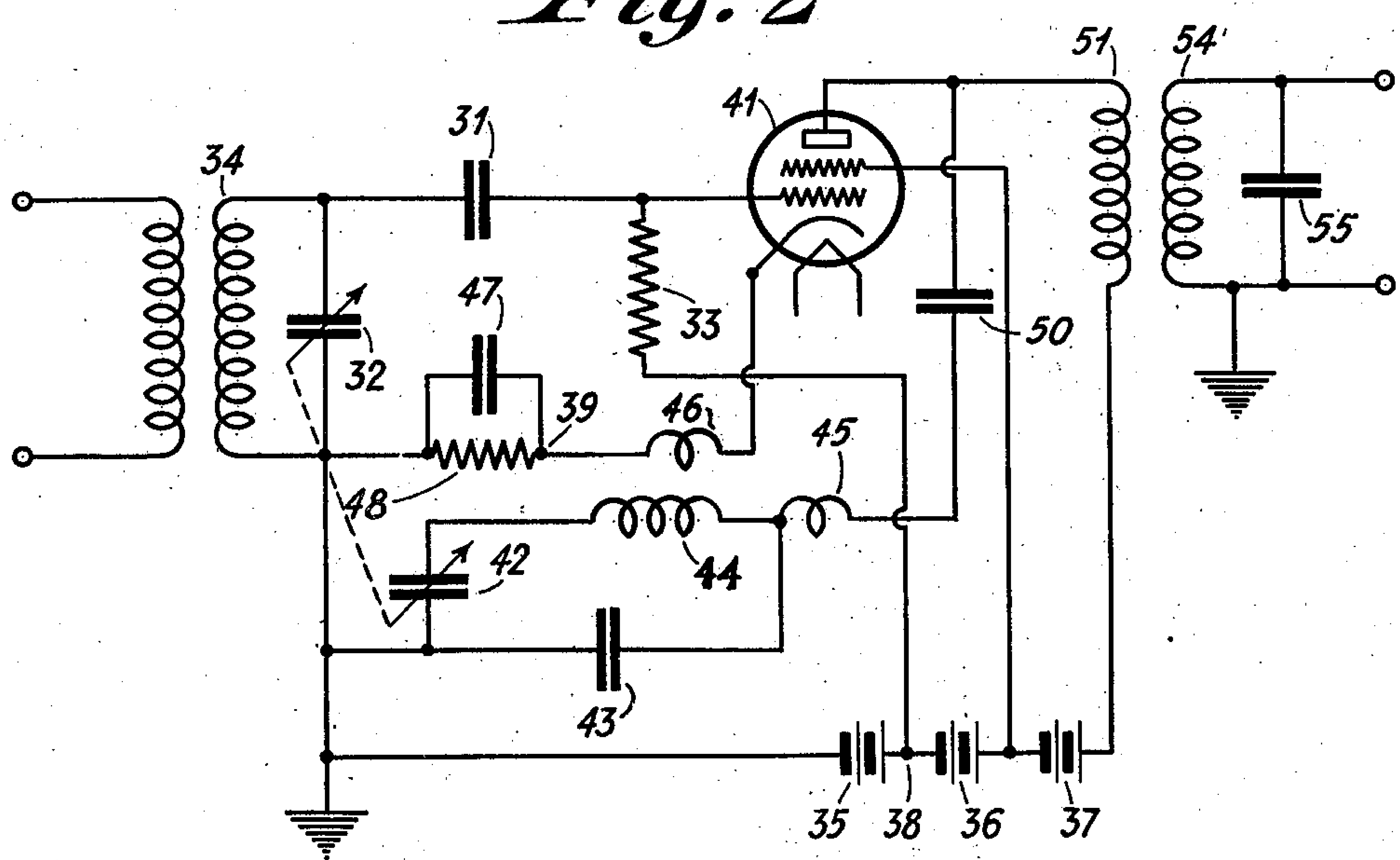


Fig. 2



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RADIORECEIVER

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Application December 14, 1931, Serial No. 580,803

13 Claims. (Cl. 250—20)

The present invention relates to an oscillator modulator, and more particularly to oscillator modulators for use in connection with superheterodyne radio receivers.

In a superheterodyne receiver it is customary to convert the desired carrier or signal frequency currents into currents of a single predetermined intermediate frequency. The intermediate frequency is usually lower than the carrier frequency to facilitate the further amplification and selection of the desired signal. This frequency-changing process has, for the best results, formerly required an oscillator and a modulator or first detector, each requiring individual tubes.

Although it has been proposed to utilize a single tube for the purpose of generating the local or heterodyne frequency currents and combining the current thus produced with the received signal currents, it has been found that a single tube could not perform both functions efficiently because of overloading effects of the oscillations, especially in the grid circuit, partly due to the widely-differing oscillation voltages obtained at the various portions of the tuning range of the oscillator. When a signal is applied from a tuned circuit to the grid of an oscillating vacuum tube, any appreciable grid current causes a damping of the tuned circuit and a distortion of the signal currents, producing also cross-modulation of the desired signal by strong interfering signals.

It is the principal object of the present invention to produce an oscillator modulator arrangement in which the oscillator shall be self-regulating to permit the grid circuit of the modulator to be free from overloading grid current at any point in the tuning range without a critical adjustment of the feed-back and without relying upon overloading or saturation effects in the plate circuit to control the amplitude of oscillation.

It is a further object of the present invention to provide an oscillator modulator circuit in which the self-regulation of the oscillator may be employed without a sacrifice of conversion gain in the modulator.

These and further objects of this invention will become apparent from the following specification taken in connection with the accompanying drawing.

For accomplishing the objects of the present invention, the oscillator modulator of a superheterodyne, for instance, is provided with a plurality of features, each aiding to prevent the grid of the oscillator modulator tube going appreciably positive relative to the cathode thereof and thus drawing space current, which would affect the selectivity of the input circuit or distort the received signals.

The first of these features is the provision of a uniform voltage oscillator arrangement in which the oscillation voltage applied to the control circuit of the modulator shall be substantially constant regardless of the frequency to which the oscillator is tuned. The oscillator may be of a uniform voltage type including a plurality of plate feed-back couplings, one of which has an effect which increases with frequency, whereas another has an effect which decreases with an increase in frequency, as the frequency is varied by the manipulation of the tuning means. Such an oscillator is described in copending application of the present inventor for "Feed-back circuits", Serial No. 540,581, filed May 28, 1931, of which this application is a continuation in part. The voltage output, then, of the oscillator circuit may be regulated within substantially narrow limits, which assists the regulator action, described hereinafter, in preventing the grid of the tube having impressed thereon a voltage sufficient to cause it to draw current.

The second feature is the provision of a resistor which is common to the plate and grid circuits of the oscillator modulator tube for the purpose of regulating the grid bias in accordance with the average plate current. This resistor is shunted by a radio-frequency by-pass condenser so that it affects only the average grid bias and is so arranged that an increase in the average plate current will result in an increase in the grid bias, which will tend to reduce the plate current, resulting in a practically stable condition. The production of oscillations tends to increase the average plate current slightly, resulting in a further increase in the grid bias, as will be described more fully hereinafter.

The third feature is the proportioning of the feed-back from the oscillation circuit. This feed-back is preferable to the cathode lead of the tube so that it is common to both the plate and grid circuits. The effective feed-back and the regulating effect of the cathode resistor are so proportioned that with the maximum voltage swing obtained, due to the effect of the oscillations upon the grid circuit, the grid will not swing positive enough to start drawing grid current, and yet the cathode resistance relative to the feed-back coupling is not sufficient to stop oscillation.

In order to permit the use of a sufficiently large resistor to give a large voltage change for a small change in plate current, it is desirable, to prevent the grid being too negative relative to the cathode, to positively bias the grid relative to the negative bias which would be obtained by the use of the entire resistor. This may be accomplished by means of a positive bias applied to the grid through a resistor, the grid being insulated from the grid circuit by a grid condenser. This constitutes the fourth feature of this invention.

In this application, the control-grid and cathode will be considered as the input terminals of a vacuum tube, the plate and cathode as output terminals, and the cathode as the common terminal. It is common practice to refer to any electron current inside of a vacuum tube as space current.

Having thus briefly described the features constituting the present invention, attention is invited to the accompanying drawing, in which:

Fig. 1 is a diagram showing a simple oscillator and illustrating the principles of the second, third and fourth features listed above, and

Fig. 2 is a diagram showing an oscillator modulator constructed in accordance with the present invention as utilized in a superheterodyne radio receiver.

In Fig. 1, to which attention is now invited, the vacuum tube 11 is a common triode having plate, grid and cathode. The tuned circuit comprises coil 12 and condenser 14, in the grid circuit. The feed-back is obtained by coupling coil 12 with coil 13 in the plate circuit. Condensers 15 and 16 are oscillation-frequency by-pass condensers. The resistance 17 is the cathode resistance referred to above, common to grid and plate circuits. The batteries 20 and 21, in series, supply the space current between plate and cathode. The tap 23 between these batteries supplies the grid bias referred to above, more positive than the negative end of resistance 17, but more negative than the cathode end (24) of this resistance. Meter 18 may be used to check the condition of zero grid current. Meter 19 may be used to check the self-regulation of the plate current, and the presence of oscillations.

The triode 11 may be of any common type, such as type UY-227 having an amplifying factor of 8. For even better results, a lower factor, such as 3, may be employed. The grid should preferably be uniformly spaced, and sufficiently extensive to completely control the flow of electrons from cathode to plate. These conditions are met by a grid with relatively open uniform spacing, made up of very fine wires. A uni-potential cathode is also preferable such as the indirectly heated type.

Resistance 17 should be from two to twenty times the effective value of the mutual resistance of the tube, under oscillating conditions, it being understood that the mutual resistance is the reciprocal of mutual conductance or, in other words, is the ratio of change in grid voltage to change in plate current.

The grid-bias voltage 21 may assume any value from zero to about half the total voltage (20 plus 21). A higher voltage 21 generally requires a higher resistance 17, and likewise causes better self-regulation.

The cathode by-pass condensers 15, 16 should be large enough to act as low impedances at the oscillator frequency. They must also be small enough to allow the self-regulation to act quickly and prevent periodic "blocking" of the oscillator. Therefore, the time constant of the total capacity of these two condensers, multiplied by the effective mutual resistance of the tube, should be somewhat less than the time constant of damped free oscillations in the tuned circuit 12, 14.

The feed-back coupling between coils 12 and 13, the resistance 17, and the voltage 21 are inter-related so that operating conditions are intermediate between the conditions of barely stopping the oscillations and of barely starting grid current. These relations are not critical, but must be satisfied within reasonable limits.

In an experimental test of the circuit of Fig. 1, the following circuit values were used: Tube 11 was type UY-227; condensers 15 and 16 were each 250 micro-microfarads; resistor 17 was 100,000 ohms; voltage 20 was 90 volts; voltage 21 was 45 volts. The feed-back coupling was varied over a ratio of 1:4 without stopping oscillations or starting grid current. The oscillating grid voltage did not exceed 15 volts. The plate current (in meter 19) remained between 0.55 and 0.7 milliampere, in spite of this wide variation of feed-back coupling and in spite of the complete absence of overloading effects, such as grid current.

In Fig. 2, a complete oscillating modulator is shown, as used in a superheterodyne receiver. The elements essential to the oscillator will be enumerated first, as follows:

The vacuum tube 41 is a common screen-grid tetrode having plate, screen-grid, control-grid and cathode. The oscillator tuned circuit comprises coil 44, fixed condenser 43, and variable tuning condenser 42. This tuned oscillator circuit is coupled to the cathode by mutual inductance between coils 44 and 46. The tunable oscillation circuit is coupled to the plate or output terminal by the uniform voltage type coupling comprising the mutual inductance between coils 44 and 45, and the condenser 43 which is common to the tuned circuit and the plate circuit. Condenser 47 is an oscillation-frequency by-pass condenser. The resistance 48 is the cathode regulating resistance, common to control-grid, screen-grid and plate circuits. The batteries 35, 36, 37, in series, supply the space current between plate or output electrode and cathode. The tap between batteries 36 and 37 supplies the screen voltage. The tap 38 between batteries 35 and 36 supplies the grid bias voltage. The high resistance grid-leak 33 and small grid condenser 31 prevent excessive grid current, which might otherwise occur under abnormal operating conditions.

The auxiliary elements in Fig. 2 which complete the oscillating modulator are enumerated as follows:

The input circuit which includes the signal-frequency tuned circuit comprising coil 34 and variable tuning condenser 32, is connected to the control-grid and cathode or input terminals of the tube 41. The incoming signal is coupled to this tuned circuit and is transferred thereby to the control-grid of the oscillating modulator. In this manner, a voltage representative of the current to be modulated by the oscillations produced by the tube is impressed between the control grid and cathode thereof. The tunable circuit, which may be preceded by a signal-frequency amplifier, if desired, is referred to as the signal input circuit of the oscillating modulator tube.

There are two intermediate-frequency tuned circuits shown. The first comprises coil 51 and condenser 50, connected in the plate circuit of tube 41. The second is loosely coupled to the first, and comprises coil 54 and condenser 55. The first circuit 50, 51 is referred to as the intermediate-frequency output circuit of the oscillating-modulator tube. The second circuit 54, 55 may be coupled to an intermediate-frequency amplifier if desired, or to a demodulator (also called the second detector of a superheterodyne receiver).

The signal input circuit 32, 34 and the oscillation circuit 42, 43, 44 are tuned simultaneously by a uni-control arrangement of condensers 32, 42. These tuned circuits are designed to have resonant frequencies differing by an amount substantially equal to the intermediate frequency. The oscillator frequency is preferably the higher. The two tuning condensers 32, 42 generally have the same capacity variation. The oscillator frequency is made higher by making coil 44 of lower inductance than coil 34. With this change alone, the frequency difference would vary in proportion to the resonant frequency of the signal input circuit. Therefore the difference at higher signal frequencies is decreased by making the effective minimum capacity of condenser 42 and its associated circuits slightly greater than that of condenser 32 and its associated circuits. Likewise, the difference at lower signal frequencies is increased by inserting the fixed condenser 43 in series with condenser 42. By proper choice of the oscillator elements 42, 43, 44 relative to the signal circuit 32, 34, the frequency difference is made exactly equal to the intermediate frequency at three points in the tuning range, and substantially constant over the entire tuning range. This is called the alignment of signal and oscillation circuits to secure the intermediate-frequency difference.

The oscillator feed-back is secured by coupling the tuned circuit 42, 43, 44 both to the plate and to the cathode of the tube 41. With simple inductive feed-back and condenser tuning, it is well known that with a uniform ratio of oscillation-circuit voltage to feedback voltage between plate and ground, the oscillation voltage across the tuned coil 44 decreases at lower frequencies due to the increase of the equivalent shunt conductance of the tuned circuit. In order to make the oscillation-circuit voltage uniform, the ratio of the feedback voltage to the oscillation-circuit voltage is varied by the provision of a plate coupling comprising a compound inductive and capacitive coupling, in aiding phase. The inductive coupling is mutual inductance between coils 44, 45 and the capacitive coupling is condenser 43. The latter has much greater effect at lower frequencies, because its reactance is greater and the reactance of the other elements 42, 44 is less. For aiding phase, the unconnected terminals of coils 44, 45 have opposite alternating polarities relative to their connected terminals.

The cathode feed-back coupling is mutual inductance between coils 44, 46, which is preferably less than half the mutual inductance 44, 45. For oscillation, the cathode and plate have like alternating polarities, the cathode alternating voltage being considerably smaller than that of the plate.

The relations of the oscillator, with regard to self-regulation, are generally the same as described for Fig. 1. The tube 41 may be a screen-grid tube of a common design, such as type UY-224. The physical relations preferred for plate, grid and cathode in Fig. 1 apply respectively to screen-grid, control-grid and cathode in Fig. 2.

The signal input circuit 32, 34 in Fig. 2, being resonant at a frequency slightly lower than the oscillator, acts as a very small capacitance at higher oscillator frequencies. Because of the appreciable inherent direct capacitance between control-grid and cathode in tube 41, a small part of the cathode feed-back voltage is impressed on the control-grid in a direction to reduce the total feed-back at higher oscillator frequencies. This effect is not serious if the direct capacitance between control-grid and cathode is kept small, as it is in the type UY-224 tube. If desired, this effect may be eliminated by (a) the use of an extra screen-grid between control-grid and cathode, or (b) the neutralization of this direct capacitance by some means, such as described in my copending application, Serial No. 739,080, entitled "Method of and means for eliminating capacitive coupling", and in my U. S. Patent No. 1,757,494 of the same title.

The coil 51 acts as a choke coil at the oscillator frequency. This coil should have a minimum distributed capacitance. The fundamental natural frequency of coil 51 should be at least half the highest tunable frequency of the oscillator, so that overtones fall outside the oscillator tuning range. This prevents any dissipation which otherwise may occur in choke coils at frequencies near even multiples of the fundamental frequency.

The condenser 50 should be considerably larger than the total other capacitance from plate to ground in tube 41, coil 51, and wiring thereto. This causes practically all of the oscillation-frequency plate current to flow back to the oscillator circuit. Also, condenser 50 should have considerably smaller capacitance than the total of condensers 42, 43. This is to reduce anti-regenerative feed-back from the intermediate-frequency output circuit to the cathode, through the oscillator circuit, which would otherwise slightly reduce the intermediate-frequency output from the oscillating modulator.

To avoid parasitic oscillations at very high frequencies, the coils 45, 46 should each be closely coupled to coil 44. The closeness of coupling is limited by the permissible amount of distributed capacitance between these coils.

In operation, the plate current flowing through the resistance 48 determines or regulates the negative bias of the grid relative to the cathode and thus regulates plate current and establishes an equilibrium. An increase in the plate current, corresponding to an increase in the amplitude of oscillations, tends to increase proportionally the negative bias which opposes the increase in plate current, thus operating to prevent a change of plate current. In an oscillator of this type, self-oscillation causes an increase in the average plate current, which, in accordance with the present invention, will cause an increase in the average grid bias. A new equilibrium point will be reached in which there is slightly greater average plate current and grid bias, and the oscillations are prevented from exceeding this amplitude.

By means of this arrangement it is easy to establish a self-regulated oscillation voltage between the grid and cathode which has a peak value, as the oscillator is tuned throughout its range, which is always smaller than the average grid bias relative to the cathode. In this way the oscillator modulator tube is prevented from drawing grid space current, and the circuits are prevented from overloading. The cathode resistance has the by-pass condenser 47 for oscillation-frequency currents, so that the bias is regulated by the average plate current only.

This self-regulating effect may be made as large as desired, depending upon the size of the resistor used. However, in order to have a regulation in which a small change in plate current tends to produce a large change in effective grid bias, the resistor may be proportioned to excessively reduce the space current and a fixed positive bias from tap 38 may be applied to the grid relative to the negative or grid end of the cathode resistor to restore the current sufficiently to sustain oscillations at a value just below that which would cause the grid to swing positive relative to the cathode. The fixed grid bias voltage is provided by battery 35 which has its positive pole connected to the grid through resistor 33, and its negative pole connected to the end of resistor 48 which is remote from the cathode. The positive bias is always kept less than the negative bias of the cathode resistor and therefore the resultant grid bias is always negative relative to the cathode or common electrode.

The feed-back from the oscillation circuit must be quantitatively related to the cathode resistor. This relation should be such that for a given value of feed-back the resistance is chosen as a mean value between that which would permit the oscillations to swing the grid positive and start grid current, and the value of resistance which would be required to stop oscillations. With a given resistor the feed-back between the oscillator and grid circuits may be adjusted to a value greater than required to start oscillations but less than required to start grid current. In other words, the permanently adjusted feed-back coupling means and the resistance are proportioned, relative to each other, to maintain the oscillations automatically at a substantial value less than the minimum value which causes the grid to swing positive relative to the cathode and draw current and thus affect the tunable input circuit but greater than the minimum value required to sustain oscillations at all frequencies as the oscillation circuit is tuned throughout its range of frequencies. This relationship is not critical, but must be met within reasonable limits.

It is important that the oscillation voltages produced by the oscillation circuit be substantially uniform throughout the entire range to which the oscillator is tuned. For this purpose it is desirable to use an oscillator, as described, in which the feed-back is varied automatically by the use of combined inductive and capacitive couplings.

A high resistance grid-leak 33 and a small grid condenser 31 are utilized as an additional precaution to prevent excessive grid current in any case where the preferred relations are not met.

The following approximate circuit constants have been found useful in the circuit of Fig. 2 and may serve as a guide in designing this circuit to meet any particular requirements: The tuning range of the signal input circuit was 550 to 1500 kilocycles, and of the oscillator circuit was 812 to 1762 kilocycles. The intermediate frequency was 262 kilocycles, the difference between signal and oscillator. The tube 41 was type UY-224. Condensers 32, 42 were on the same shaft, and had 350 micro-microfarads maximum capacitance. Condenser 43 was 550 micro-microfarads. Coil 34 had 250 microhenrys, and coil 44, 160 microhenrys. Mutual inductance 44, 46 was 25 microhenrys and mutual inductance 44, 45 was 55 microhenrys. Condenser 47 was 500 micro-microfarads and resistor 48 was 30,000 ohms. Condenser 31 was 50 micro-microfarads and resistor 33 was one megohm. Condenser 50 was about 50 micro-microfarads and coil 51 was about 5 millihenrys.

The voltages 35, 36, 37 were respectively 30, 60 and 90 volts, giving 30 volts on the control-grid, 90 volts on the screen-grid and 180 volts on the plate.

It is to be understood that whereas the oscillator modulator embodying this invention is primarily for the purpose of superheterodyne radio receivers in which the grid circuit is coupled to the input of a radio receiver or the output of a radio-frequency amplifier tube and the plate circuit of the oscillator modulator is coupled to an intermediate-frequency tuned circuit, the oscillator modulator described may be utilized in any other suitable connection, and its use in a superheterodyne is therefore not to be construed as a limitation of the invention.

Furthermore, whereas the above-noted improvements have been found especially useful in radio-frequency circuits, it is to be understood that the principles involved are equally applicable for use in connection with vacuum tube circuits operating at any desired frequency. Also, the principles involved may be useful in connection with heterodyne, self-heterodyne or autodyne methods of receiving radio-frequency signals in which the oscillator modulator produces an audio beat. Similarly, the elements constituting the present invention may be utilized in connection with a homodyne or zero beat receiver. Oscillators of this type may be readily synchronized when tuned approximately to a master oscillator or to a harmonic of a master oscillator. Oscillators of this type have also been found exceptionally free from "drifting" and from effects of different tubes on the oscillation frequency.

What is claimed is:

1. An oscillator-modulator circuit comprising a vacuum tube having a control grid circuit for receiving a voltage representative of a current to be modulated and an output circuit, a tunable oscillation circuit, means independent of grid current of said tube for developing and applying to said grid circuit a bias voltage increasing negatively substantially in proportion to the amplitude of oscillations, and coupling means between said output and grid circuits and said oscillation circuit proportioned to feed back to said grid circuit a portion of the oscillation circuit voltage so variable over the tunable range of said oscillation circuit as automatically to maintain said oscillations at a substantial value less than the minimum value which causes the grid to swing positive.

2. An oscillator-modulator comprising a vacuum tube having an anode, a control grid and a cathode and circuits associated therewith, said grid circuit being adapted to receive signal voltages to be modulated, a tunable oscillation circuit, means for providing an initial negative grid bias increasing negatively in proportion to the amplitude of oscillations, and coupling means between said anode and grid circuits and said oscillation circuit permanently adjusted to feed back to said grid circuit a portion of the oscillation circuit voltage which is substantially greater than that required to sustain oscillations but less than that required to cause the grid to swing positive relative to the cathode over the tunable range of said oscillation circuit.

3. An oscillator-modulator comprising a vac-

uum tube having an anode, a cathode and a control grid and circuits associated therewith, said grid circuit being adapted to receive signal voltages to be modulated, a tunable oscillation circuit including a tuning device, means for providing an initial negative grid bias increasing negatively in proportion to the amplitude of oscillations, and coupling means between said anode and grid circuits and said oscillation circuit permanently adjusted to feed back to said grid circuit a portion of the oscillation circuit voltage which is substantially greater than that required to sustain oscillations but less than that required to cause the grid to swing positive relative to the cathode over the tunable range of said oscillation circuit, said coupling means including a coupling variable in response to adjustment of said tuning device.

4. An oscillator-modulator comprising a vacuum tube having an anode, a cathode and a control grid and circuits associated therewith, a tunable oscillation circuit, said grid circuit being adapted to receive signal voltages to be modulated, coupling means between said anode and grid circuits and said tunable oscillation circuit, a high resistance cathode bias resistor in said grid circuit tending excessively to reduce the space current of said tube, a fixed source of initial positive bias voltage connected to said grid circuit, said resistor and said source being so proportioned relative to the tube and circuit constants as to maintain the resultant grid bias above that sufficient to sustain oscillations and below that which causes the grid to draw grid current.

5. An oscillator-modulator comprising a vacuum tube having an anode, a cathode and a control grid and circuits associated therewith, a tunable oscillation circuit, said grid circuit being adapted to receive signal voltages to be modulated, coupling means between said anode and grid circuits and said tunable oscillation circuit, a high resistance having one end connected to said cathode, and a fixed source of grid bias voltage having its positive pole connected to said grid and its negative pole connected to the other end of said resistance, said resistance and voltage being proportioned to sustain the oscillations at a value just below that which causes the grid to swing positive relative to the cathode and thus draw grid current.

6. In an oscillator modulator, the combination of a vacuum tube having input, output and common terminals, an input circuit connected to said input and common terminals and including a tunable circuit, a tunable oscillation circuit coupled to said output terminal, said last-mentioned coupling being of a uniform voltage type, a feed-back coupling between the oscillation circuit and input circuit, means for supplying a bias to the input terminal relative to said common terminal, and a resistor in the lead to the common terminal for regulating said bias, said bias supply means, said resistor and said last-mentioned feed-back coupling being so proportioned that as the oscillation circuit is tuned throughout its range of frequencies the feed-back will be sufficient at all times to maintain oscillations but insufficient to swing the input terminal positive and thus cause it to draw space current and affect said tunable input circuit.

7. In an oscillator-modulator, a vacuum tube having control-grid, plate and cathode, a tunable oscillation circuit coupled to said plate, said coupling comprising two couplings whereby a substantially uniform amplitude oscillation current is produced as the frequency of oscillations is varied over the tuning range of the oscillation circuit, a feed-back coupling between said oscillation circuit and the input circuit of said tube, a high resistance having one end connected to said cathode, and a fixed grid bias means having its positive pole connected to said grid and its negative pole connected to the other end of said resistance, said resistance, grid bias means, and feed-back coupling being proportioned to sustain the oscillations at a value just below that which causes the grid to swing positive relative to the cathode and thus draw grid current as the oscillation circuit is tuned.

8. In an oscillator modulator, the combination of a vacuum tube having input, output and common terminals, an input circuit connected to said input and common terminals and including a tunable circuit, a tunable oscillation circuit coupled to said output terminal, a feed-back coupling between the oscillation circuit and the input circuit, means for supplying a bias to the input terminal relative to said common terminal, a resistor in the lead to the common terminal for regulating said bias, said last-mentioned feed-back coupling being so proportioned that as the oscillation circuit is tuned throughout its range of frequencies the feed-back will be sufficient at all times to maintain oscillations but insufficient to swing the grid positive and thus cause it to draw grid current and affect the tuned input circuit.

9. In an oscillator modulator, the combination of a vacuum tube having input, output and common terminals, an input circuit connected to said input and common terminals and including a tunable circuit, a tunable oscillation circuit coupled to said output terminal, a feed-back coupling between the oscillation circuit and the input circuit, a high resistance in the lead to the common terminal for regulating the bias, but which excessively reduces the space current from the common terminal, and means independent of said resistance for providing an input terminal bias voltage more positive than the negative end of said resistance, which bias restores the current sufficiently to sustain oscillations, said feed-back coupling being so proportioned that as the oscillation circuit is tuned throughout its range of frequencies the feed-back will be sufficient at all times to maintain oscillations but insufficient to swing the grid positive and thus cause it to draw grid current and affect the tuned input circuit.

10. In an oscillator modulator, the combination of a vacuum tube having control grid, cathode and plate, means for normally biasing said grid negatively, an input circuit coupled to said control grid and including a tunable circuit, an output circuit connected to said plate, a tuned oscillation circuit coupled to said output circuit, said coupling including one portion the reactance of which increases with frequency, and a second portion the reactance of which decreases with frequency by a substantially corresponding amount, whereby the amplitude of the oscillations produced remains substantially constant as the circuit is tuned, and a feed-back coupling between said oscillation circuit and the input circuit, said coupling being so proportioned that the maximum oscillation voltage impressed upon the input circuit as the oscillation circuit is tuned shall be insufficient to overcome said negative bias and swing the grid positive and thus cause it to draw grid current and yet sufficient to continue oscillations as said tunable circuits are tuned over a desired frequency range.

11. In an oscillator modulator, the combination of a vacuum tube having control grid, cathode and plate, means for normally biasing said grid negatively, an input circuit coupled to said control grid and including a tunable circuit, tuned to the frequency of the signals being received, a tuned output circuit connected to said plate, tuned to a fixed difference frequency, a tuned uniform-gain oscillation circuit coupled to said output circuit, tuned to a frequency differing from the frequency of the signals being received by said fixed difference frequency, and a feed-back coupling between said oscillation circuit and the input circuit, said coupling being so proportioned that the maximum oscillation voltage impressed upon the input circuit as the oscillation circuit is tuned shall be insufficient to overcome said negative bias and swing the grid positive and thus cause it to draw grid current and yet sufficient to continue oscillations as said tunable circuits are tuned over a desired frequency range.

12. In an oscillator modulator, the combination of a vacuum tube having control grid, cathode and plate, means for normally biasing said grid negatively, an input circuit coupled to said control grid and including a tunable circuit, tuned to the frequency of the signals being received, a tuned output circuit connected to said plate, tuned to a fixed difference frequency, a tuned oscillation circuit coupled to said output circuit, tuned to a frequency differing from the frequency of the signals being received by said fixed difference frequency, said coupling including a plurality of couplings whereby the oscillations produced remain substantially constant as the circuit is tuned, a feed-back coupling between said oscillation circuit and the input circuit, said coupling being so proportioned that the maximum oscillation voltage impressed upon the input circuit as the oscillation circuit is tuned shall be insufficient to overcome said negative bias and swing the grid positive and thus cause it to draw grid current and yet sufficient to continue oscillations as said tunable circuits are tuned over a desirable frequency range, and means for simultaneously tuning said input and oscillation circuits to respond to frequencies which differ by a substantially constant amount throughout the broadcast band.

13. In an oscillator modulator, the combination of a vacuum tube having control grid, cathode and plate, means for normally biasing said grid negatively, a tuned input circuit coupled to said control grid, an output circuit connected to said plate, a tuned oscillation circuit coupled to said output circuit, said coupling including a plurality of couplings, each of said couplings having a reactance which changes oppositely and at a corresponding rate with changes of frequency, and a feed-back coupling between said oscillation circuit and the input circuit, said coupling being so proportioned that the maximum oscillation voltage impressed upon the input circuit as the oscillation circuit is tuned shall be insufficient to overcome said negative bias and swing the grid positive and thus cause it to draw grid current and yet sufficient to continue oscillations as said tunable circuits are tuned over a desired frequency range.

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