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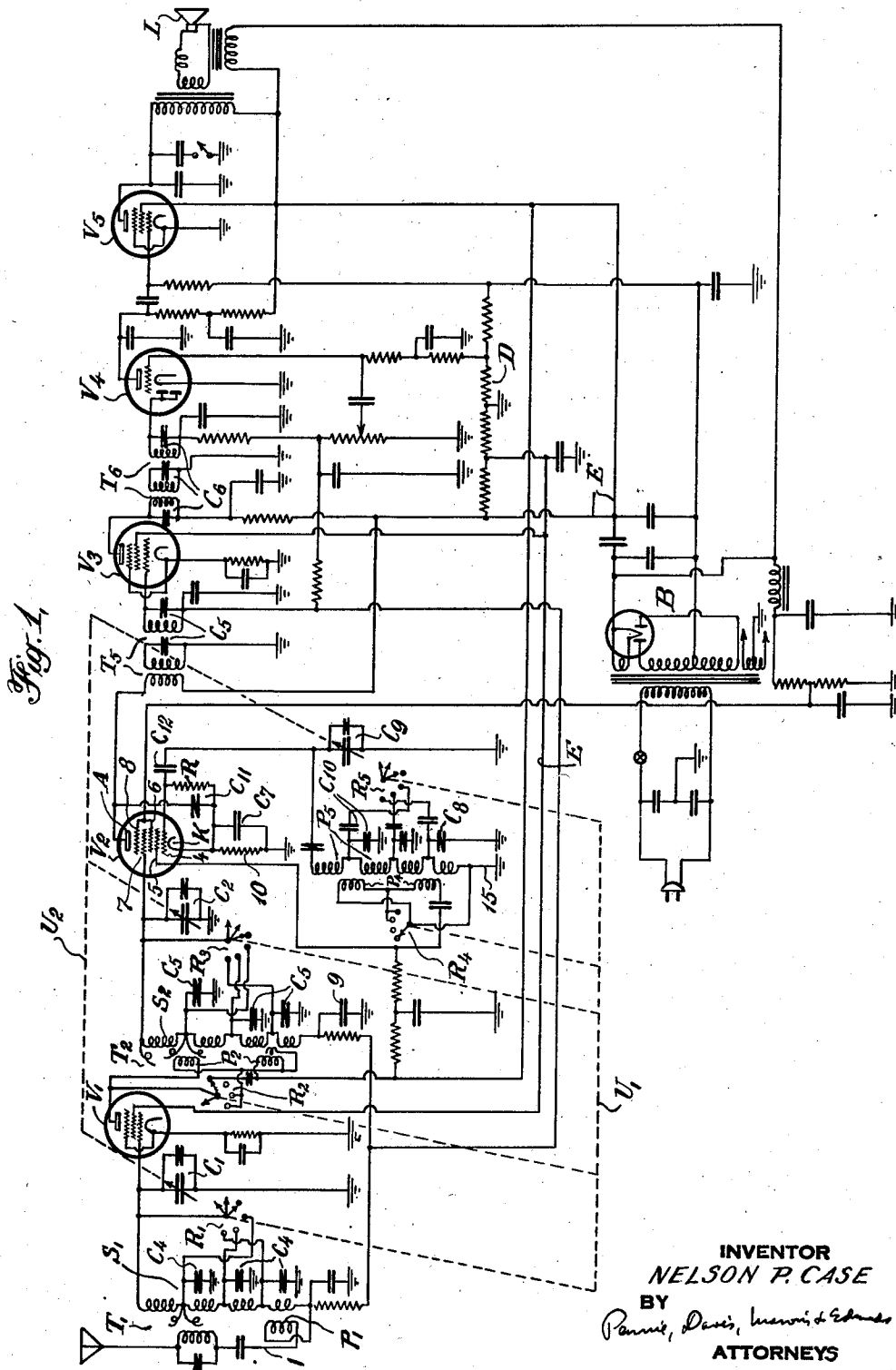
N. P. CASE

2,045,569

HIGH FREQUENCY SYSTEM

Filed April 25, 1934

3 Sheets-Sheet 1



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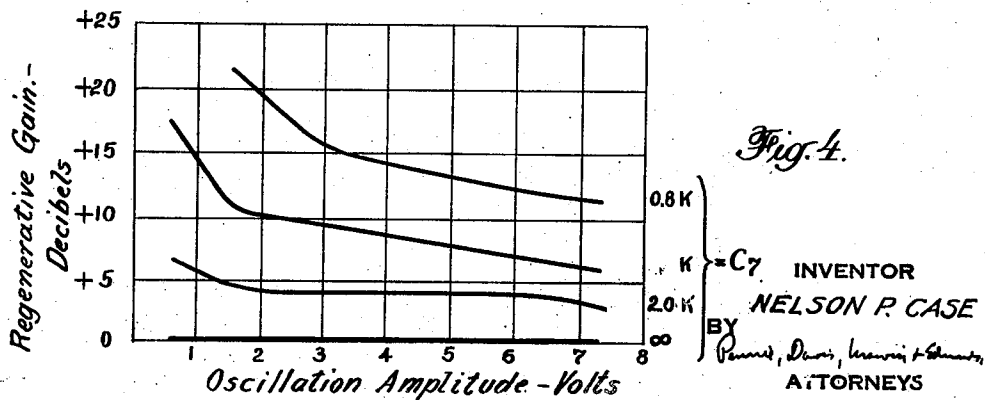
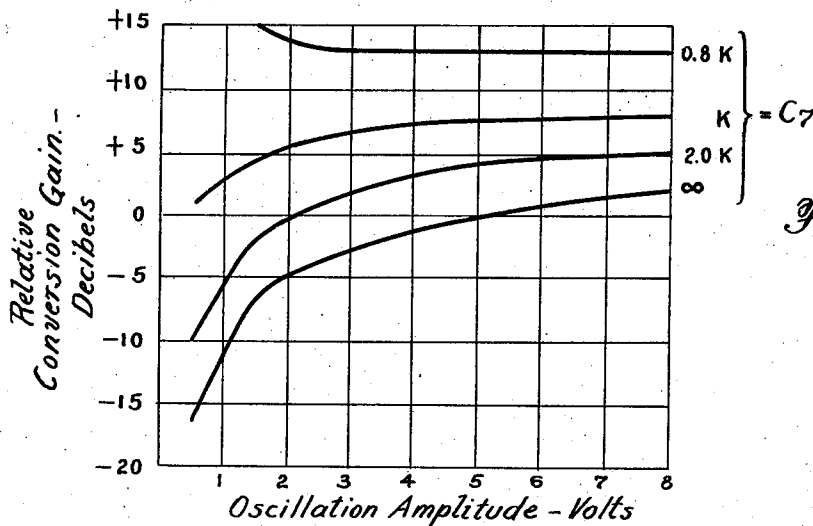
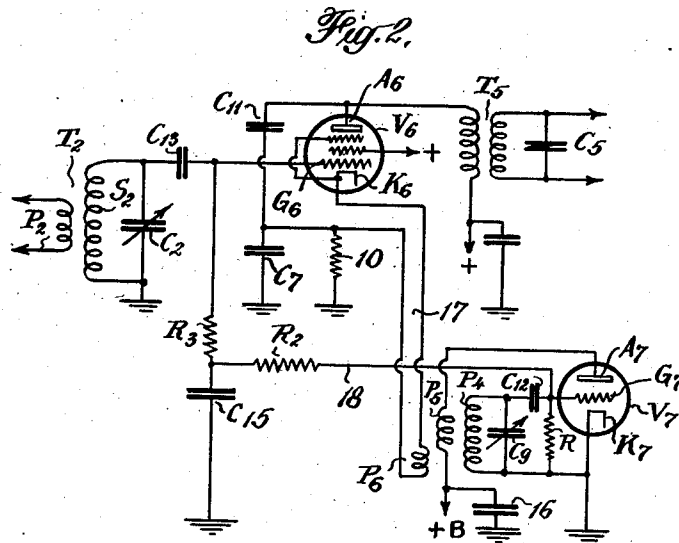
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HIGH FREQUENCY SYSTEM

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INVENTOR
NELSON P. CASE
BY
Pomeroy, Davis, Leavitt & Schenck
ATTORNEYS

June 30, 1936.

N. P. CASE

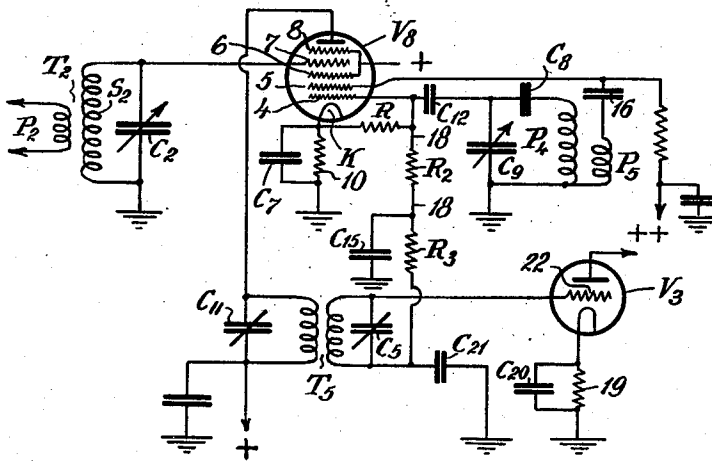
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Fig. 5.



INVENTOR
NELSON P. CASE
BY
Perris, Davis, Harms + Edwards,
ATTORNEYS

UNITED STATES PATENT OFFICE

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HIGH FREQUENCY SYSTEM

Nelson P. Case, Bayside, N. Y., assignor to Hazeltine Corporation, Jersey City, N. J., a corporation of Delaware

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12 Claims. (Cl. 250—20)

This invention pertains to systems of electrical communication by means of carrier wave signals; more especially to heterodyne vacuum tube radio broadcast receiving systems.

5 The invention is particularly applicable to so-called "all wave" receivers operative over a frequency range considerably in excess of the present broadcast band of 550 to 1500 kilocycles. An object of the invention is to secure an over-all gain which remains substantially constant throughout the entire "all wave" range of the receiver.

15 In a heterodyne system, the "conversion" gain is determined in large measure by the performance of the heterodyne oscillator. Conversion gain is defined as the ratio of the modulated signal voltage at the output of the modulator to the reception frequency signal voltage at the input of the modulator. If the oscillation amplitude of the heterodyne source decreases, as is usually the case at extremely high frequencies, the amplitude of the modulated signal, and hence the conversion gain, will likewise decrease.

20 It is proposed in accordance with the present invention to compensate or minimize variations in intensity of the modulated signals otherwise resulting from such changes in oscillation amplitude, by utilizing a biasing voltage derived from the heterodyne oscillations, and automatically to control the amplification or gain of the receiving system in inverse relation to the oscillation amplitude, so that as the oscillation amplitude decreases the gain will be automatically increased to maintain the over-all gain substantially constant.

25 A biasing voltage varying with the oscillation amplitude is conveniently secured by associating a blocking condenser-leak resistance combination with a grid of the oscillator. The biasing voltage thus derived may be applied to the control electrodes of one or more of the reception frequency or modulated frequency amplifier tubes to adjust the signal amplification inversely to the amplitude of oscillations.

30 Alternatively the modulating element of the system may be rendered regenerative, as by regeneratively coupling its input and output circuits, and the oscillator grid biasing voltage applied to the modulator to control the regenerative gain. If, with this modification, separate tubes are employed for the oscillator and modulator, the biasing voltage is applied to the modulator control grid. In the case of a single multi-grid tube, such as a hexode, serving as a combined oscillator-modulator, wherein oscillations are produced by the inner triode section including the cathode, and

modulation effected by the outer tetrode section including the anode, a virtual cathode is established between oscillator and modulator portions, the emission of which is automatically regulated inversely to the biasing voltage established on the oscillator grid. The mutual conductance of the outer tetrode section, and hence the regenerative gain, varies with the emission of the virtual cathode.

5 With any of the mentioned modifications, when the oscillation amplitude is large, the average negative bias derived from the oscillator, is likewise large. This produces a relatively low mutual conductance in the biased amplifier or modulator elements, resulting in a small gain of the signals. Conversely when the oscillation amplitude is small, the negative biasing voltage is likewise small, and the mutual conductance of the biased elements correspondingly high, giving greatly increased gain. By suitably proportioning the circuit components, in the manner described below, the change in amplification may be caused to compensate to a desired extent for variations in the oscillation amplitude, and such preferably as to maintain the over-all gain substantially constant throughout a considerable range of variation in oscillation amplitude.

In the drawings:

Figure 1 is a circuit diagram of a super-heterodyne receiving system employing the invention, wherein a single multi-grid tube functions as a combined oscillator and regenerative modulator.

Figure 2 shows diagrammatically the oscillator-modulator portion of a system, such as that of Fig. 1, but modified to employ separate oscillator and modulator tubes.

Figures 3 and 4 are comparative performance graphs illustrating the conversion gain and the amount of regeneration present for various oscillation amplitudes and regenerative couplings in systems such as those of Figures 1 and 2.

Figure 5 shows diagrammatically the oscillator-modulator and first stage of modulation frequency amplification of a system, such as that of Figure 1, but modified to control the gain of the modulation frequency amplifier, instead of controlling the regenerative gain of the modulator.

Referring to Figure 1, the system disclosed comprises in cascade arrangement a stage of tuned radio-frequency amplification, tube V₁, operating into an oscillator-modulator, tube V₂, the modulated output of which is applied to a stage of intermediate-frequency amplification, tube V₃, followed by a combined detector and

stage of $a-f$ amplification, tube V_4 , and a stage of audio-frequency amplification, tube V_5 , the output of which is applied to a loud speaker L . The system is energized from the usual rectifier-filter combination B , for converting the house supply of alternating current into substantially non-pulsating uni-directional voltage applied to the voltage distributing resistors D . The manner of supplying voltages to the individual tubes over conductors such as E , is obvious from the drawings and requires no detailed discussion.

High-frequency signals are supplied to the system from an antenna circuit I coupled to the input of tube V_1 through a transformer T_1 , comprising a primary coil P_1 and a secondary coil S_1 tuned by a variable condenser C_1 . A somewhat similar tuned transformer coupling T_2 , C_2 is employed between tubes V_1 and V_2 . The secondary coil S_1 of transformer T_1 , together with the primary P_2 and secondary S_2 coils of transformer T_2 are tapped at intermediate points to contacts of rotary switches R_1 , R_2 and R_3 , respectively, for adjusting the system to operate over successive frequency bands of the "all wave" range. The rotary switch arms are ganged to a unitary control U_1 to provide simultaneous band adjustments of all circuit components. Likewise the tuning condensers C_1 and C_2 are ganged to a unitary control U_2 for simultaneously tuning the circuits by continuous gradation throughout each frequency band. Certain portions of coils S_1 and S_2 are individually shunted to ground by semi-adjustable padding condensers such as C_3 and C_5 as a means of aligning the tuned circuits.

Tubes V_2 , V_3 and V_4 are coupled in cascade by means of transformers T_3 and T_4 tuned to the intermediate frequency by means of semi-adjustable condensers C_6 and C_8 arranged in shunt to the transformer windings. The circuit connections for the detector V_4 , audio-frequency amplifier V_5 , and loud speaker L are apparent from the drawings.

The oscillator-modulator tube V_2 contains within its single glass receptacle: a cathode K , an anode A , and a plurality of grids successively disposed therebetween, which may, for purposes of this disclosure, be designated as an inner oscillator grid 4, an oscillator anode grid 5, an inner screen 6, the signal control grid 7, and an outer screen 8.

For impressing upon the oscillator-modulator, tube V_2 , high-frequency signals impinging on the antenna circuit I , the secondary coil S_2 , of transformer T_2 has its high-potential terminal connected to the signal control grid 7, the low-potential end of coil S_2 being grounded at high frequencies through the by-pass condenser 9. The cathode K of tube V_2 is effectively grounded at the reception and heterodyne frequencies through the by-pass condenser C_7 shunting the biasing resistor 10.

The inner triode section of tube V_2 comprising the cathode K and grids 4 and 5, is adapted by means of the associated impedances external to the tube, to generate oscillations of heterodyne frequency. Thus the grids 4 and 5 are connected respectively through magnetically coupled coils P_4 and P_5 to ground at 15. The cathode K is likewise, as stated, effectively grounded at the heterodyne frequency through the by-pass condenser C_7 . The circuits thus traced from grids 4 and 5 through ground to the cathode K , are regeneratively coupled by virtue of the magnetic coupling between coils P_4 and P_5 , which are properly poled to this end. This regenerative coupling

is such as to establish and maintain sustained oscillations throughout the "all wave" operating range of the system. The frequency of oscillation is dependent upon the magnitudes of the self and mutual impedances of coils P_4 and P_5 , as well as upon the setting of the tuning condenser C_3 arranged in shunt to coils P_5 .

As in the case of transformers T_1 and T_2 , coils P_4 and P_5 are tapped at intermediate points to rotary switches R_4 and R_5 respectively, ganged to the unitary control U_1 , to adapt the heterodyne frequency to serve the particular reception band to which the receiver is adjusted by the settings of switches R_1 , R_2 and R_3 . Padding condensers such as C_8 and C_{10} , are associated with individual tapped portions of coil P_5 for purposes of aligning the several tuned circuits for actuation by the unitary control U_2 mechanically coupled to condenser C_3 as well as to condensers C_1 and C_2 .

Coils P_4 and P_5 are largely responsible for variations in the amplitude of heterodyne oscillations with frequency change. Within a given frequency band, the oscillation amplitude increases with frequency in consequence of the increase in self and mutual impedances of coils P_4 and P_5 . Also as the operating range is adjusted from a frequency band of lower to one of higher order, the average amplitude of oscillation will in general decrease, due to the decreasing self and mutual impedances of coils P_4 and P_5 , which results from tapping to successively smaller portions thereof.

Alterations in the oscillation amplitude produced by these and other factors are, in accordance with the present invention, compensated for in the manner stated, by regeneratively amplifying the modulated signals in the outer tetrode section of the tube, which includes the signal control grid 7 and the anode A , and causing the extent of this regenerative amplification to be varied in inverse relation to change in the oscillation amplitude.

This regenerative energy transfer is accomplished by connecting the intermediate-frequency tuning condenser C_{11} , from the anode A , directly to the cathode K . The cathode K is, at the modulated or intermediate frequency, maintained considerably above ground potential by the impedance of condenser C_7 . The signal control grid 7, however, is, at the intermediate frequency, effectively grounded through coil S_2 and by-pass condenser 9, which have relatively small impedances at this frequency. Accordingly, at the intermediate frequency, the anode A and the control grid 7 assume opposite instantaneous alternating current polarities with respect to the cathode K , which is the requisite condition for regenerative feedback.

The percentage of energy thus regeneratively transferred from the anode circuit to the signal control grid circuit of tube V_2 , is determined by the capacity ratio of condensers C_{11} and C_7 and by mutual conductance between the signal control grid 7 and the anode A . The mutual conductance referred to is, in accordance with this invention, caused to vary inversely to the amplitude of heterodyne oscillation by virtue of the blocking condenser C_{12} and the leak resistor R associated with the inner oscillator grid 4. Thus when the amplitude of oscillation is large, the average negative bias on grid 4 is likewise large, and the mutual conductance in the outer tetrode section of the tube correspondingly small. As the oscillation amplitude decreases, the average negative biasing potential on grid 4 likewise decreases, in con-

sequence of which the mutual conductance in the outer tetrode section of the tube increases.

In this way the energy regeneratively transferred at the intermediate frequency from the output circuit associated with anode A to the input circuit associated with the control grid 7, is caused to vary inversely with the amplitude of oscillation. By suitably proportioning the capacity of condenser C_7 in relation to that of condenser C_{11} , the conversion gain of tube V_2 between its input and output circuits, may be caused to remain reasonably independent of variations in the oscillator amplitude throughout the entire "all wave" range of the system.

Fig. 2 illustrates the invention as applied to a system employing separate modulator V_6 and oscillator V_7 tubes. Incoming signals are applied through transformer T_2 , having a secondary S_2 , tuned by C_2 to the reception frequency, to the signal control grid G_6 of the modulator, the modulated output being relayed to the remainder of the system through the tuned transformer T_3 . The modulated output is regeneratively amplified in tube V_6 by virtue of the condensers C_{11} and C_7 effectively connected between the anode A_6 and the cathode K_6 , and between the grid G_6 and the cathode, respectively.

In the oscillator circuit, a tuned impedance consisting of coil P_4 shunted by variable condenser C_9 , is connected between grid G_7 and the grounded cathode K_7 , of tube V_7 . The anode A_7 is grounded through a coil P_5 and a by-pass condenser 16. Coil P_5 is so coupled magnetically to coil P_4 , as to produce sustained oscillations of a frequency determined by the setting of condenser C_9 . The oscillations are applied between ground and the cathode of the modulator tube V_6 , over a connection 17, which includes a coil P_6 magnetically coupled to coils P_4 and P_5 .

The blocking condenser C_{12} , in series with the grid G_7 of tube V_7 , and the leak resistance R between grid and cathode of tube V_7 , provide a biasing voltage derived from the oscillation amplitude, which is applied over a connection 18 to the signal control grid G_6 of the modulator. This connection includes series resistances R_2 and R_3 , the intermediate point of which is grounded through a by-pass condenser C_{15} , for filtering out pulsating components of the biasing voltage.

In the operation of the Fig. 2 circuit, the increased bias on the oscillator grid resulting from an increase in oscillation amplitude, is applied over conductor 18 to the modulator grid, thereby decreasing the modulator mutual conductance and with it the regenerative amplification of the modulated signals. The converse of this chain of reactions is produced by a decrease in the oscillation amplitude.

Fig. 3 illustrates by means of comparative graphs the effect on the conversion gain of altering the capacity of condenser C_7 , condenser C_{11} remaining fixed except for the necessary retuning. Selecting a value K for this condenser affords a reasonably constant conversion gain for wide variations in the oscillation amplitude of the order of one to eight volts. It will be apparent from the graphs that the adjustment of condenser C_7 is, however, fairly critical, and should not vary by more than say plus or minus ten percent from the value K . If a capacity of approximately $.8 K$ is employed, the regeneration tends to produce oscillations for small amplitudes of the heterodyne oscillator. On the other hand, if the capacity K is doubled, the conversion gain falls off

appreciably for small amplitudes of heterodyne oscillator. The curve for $C_7 = \infty$ gives the relation between the oscillator amplitude and the conversion gain for the condition that the regenerative coupling is omitted.

Fig. 4 shows for the C_7 capacity values of Fig. 3, the amount of regenerative amplification provided by the modulator for various amplitudes of heterodyne oscillations.

Fig. 5 illustrates the invention as applied to a system employing a multi-grid tube, V_8 , as a combined oscillator and non-regenerative modulator, the gain control being applied to the modulation frequency amplifier tube, V_3 . Incoming signals are applied through transformer T_2 , having a secondary S_2 , tuned by C_2 to the reception frequency, to the signal control grid 7 of the modulator section of tube V_8 , the modulated output being relayed to the modulation frequency amplifier tube V_3 through the tuned transformer T_3 .

In the oscillator circuit, a tuned impedance consisting of coil P_4 shunted by variable condenser C_9 is connected between grid 4 and cathode K of tube V_8 , through the by-pass condenser C_7 . The oscillator anode grid 5, is likewise connected to the cathode K , through condenser 16, coil P_5 , and by-pass condenser C_7 . Coil P_5 is so coupled magnetically to coil P_4 , as to produce sustained oscillations of a frequency determined by the setting of condenser C_9 . The oscillations serve to produce modulation of the signals applied to control grid 7 by virtue of their effect of varying the emission of the virtual cathode which exists between the inner screen 6 and the signal control grid 7.

For low amplitudes of oscillation, the conversion gain of the tube V_8 varies directly with the oscillation amplitude.

The blocking condenser C_{12} , in series with the grid 4 of tube V_8 , and the leak resistance R between grid 4 and cathode K of tube V_8 , provide a biasing voltage derived from the oscillation amplitude, which is applied over a connection 18 to the signal control grid 22 of the modulation frequency amplifier tube V_3 . This connection includes series resistances R_2 and R_3 , and by-pass condensers C_{15} and C_{21} , for filtering out pulsating components of the biasing voltage.

In the operation of the circuit of Fig. 5, the increased bias on the oscillator grid 4 resulting from an increase in oscillation amplitude, is applied over conductor 18 to the amplifier grid 22, thereby decreasing the mutual conductance of the modulation frequency amplifier tube V_3 and with it the amplification of the modulated signals secured by means of tube V_3 . The converse of this chain of reactions is produced by a decrease in the oscillation amplitude.

I claim:

1. In a heterodyne signaling system, a vacuum tube modulator, a source of heterodyne oscillations for modulating signals, said oscillations being subject to undesired changes in amplitude, and means reducing the effects of said changes on intensity of the modulated signals comprising, means rendering said modulator regenerative to modulated signals, and means responsive to said source for varying the regeneration of said modulator inversely to said changes in oscillation amplitude.

2. In a heterodyne signaling system, a vacuum tube modulator, a source of heterodyne oscillations for modulating signals, said oscillations

being subject to undesired changes in amplitude, and means minimizing the effects of said changes on intensity of the modulated signals comprising, means rendering said modulator regenerative to said modulated signals, and means responsive to said heterodyne oscillations for varying the regeneration of said modulator inversely to said changes in oscillation amplitude.

3. In a heterodyne signaling system, a vacuum tube modulator, a source of heterodyne oscillations for modulating signals, said oscillations being subject to undesired changes in amplitude, and means substantially compensating the effects of said changes in oscillation amplitude on intensity of the modulated signals comprising, means rendering said modulator regenerative to modulated signals, and means responsive to said heterodyne oscillations for so adjusting the regeneration of said modulator inversely to said changes in oscillation amplitude as substantially to counterbalance the effects of said changes in oscillation amplitude on the modulated signals.

4. In a heterodyne receiving system, a vacuum tube modulator, a source of heterodyne oscillations for modulating signals, said oscillations being subject to undesired changes in amplitude, and means reducing the effects of said changes on intensity of the modulated signals comprising, means rendering said modulator regenerative to modulated signals, and means responsive to said heterodyne oscillations for varying, in inverse relation to the amplitude of said oscillations, the mutual conductance of said modulator and thereby the extent of its regeneration.

5. In a superheterodyne radio receiving system, a vacuum tube modulator, a source of heterodyne oscillations for modulating signals, said oscillations being subject to undesired changes in amplitude, and means reducing the effects of said changes on the intensity of the intermediate frequency signals comprising, means rendering said modulator regenerative to intermediate frequencies, and means responsive to said heterodyne oscillations for varying the regeneration of said modulator inversely to said changes in oscillation amplitude.

6. In a heterodyne signaling system, a multi-grid vacuum tube consisting of an inner section including a pair of grids and a cathode, and an outer section including a signal control grid and an anode, means adapting said inner section to generate heterodyne oscillations, means adapting said outer section to modulate signals therewith, said heterodyne oscillations being subject to undesired changes in amplitude, and means reducing the effects of said changes on intensity of the modulated signals comprising, means rendering said outer section regenerative to modulated signals, and means applying to a grid of said inner section a negative biasing potential derived from said heterodyne oscillations for varying the modulated signal regeneration inversely to said changes in oscillation amplitude.

7. In a heterodyne signaling system, a multi-grid vacuum tube consisting of an inner section including a pair of grids and a cathode, and an outer section including a signal control grid and an anode, means adapting said inner section to generate heterodyne oscillations, means adapting said outer section to modulate signals therewith, said heterodyne oscillations being subject to undesired changes in oscillation amplitude, and means reducing the effects of said changes on

intensity of the modulated signals comprising, means rendering said outer section regenerative to modulated signals, and a grid-leak associated with a grid of said inner section for varying the mutual conductance and thereby the regeneration of the outer section inversely to said changes in oscillation amplitude.

8. In a heterodyne receiving system an oscillator-modulator comprising a vacuum tube having successively disposed between a cathode and an anode thereof, an inner grid, an oscillator anode grid, and a control grid responsive to signals, means reactively coupling said inner and oscillator anode grids to said cathode to produce heterodyne oscillations for modulating signals, said oscillations being subject to undesired changes in amplitude, and means reducing the effects of said changes on intensity of the modulated signals comprising, a regenerative coupling between said anode and control grid for regeneratively amplifying the modulated signals, and means applying to said inner grid a negative biasing voltage derived from said heterodyne oscillations.

9. In a heterodyne receiving system an oscillator-modulator comprising, a vacuum tube having successively disposed between a cathode and an anode thereof, an inner grid, an oscillator anode grid, and a control grid responsive to signals, means reactively coupling said inner and oscillator anode grids to said cathode to produce heterodyne oscillations for modulating signals, said oscillations being subject to undesired changes in amplitude, and means reducing the effects of said changes on intensity of the modulated signals comprising, a regenerative coupling between said anode and control grid for regeneratively amplifying the modulated signals, and a grid-leak associated with said inner grid for applying thereto a negative biasing voltage derived from said heterodyne oscillations.

10. In a heterodyne signaling system, a vacuum tube modulator having an anode, a cathode and a control grid, a source of heterodyne oscillations subject to variations in amplitude, and means reducing the effects of said variations on the modulated signals comprising, a regenerative coupling for said modulator selectively responsive to the modulated signals, said coupling including a pair of capacities effectively connected between said anode and cathode and between said cathode and grid respectively, the ratio of said capacities determining the extent of said regeneration, and means deriving a biasing voltage from said source of heterodyne oscillations for varying said regeneration inversely to changes in the oscillation amplitude.

11. In a heterodyne signaling system, a vacuum tube modulator having an anode, a cathode and a control grid, a source of heterodyne oscillations subject to variations in amplitude, and means reducing the effects of said variations on the modulated signals comprising, a regenerative coupling for said modulator selectively responsive to the modulated signals, said coupling including a pair of capacities effectively connected between said anode and cathode and between said cathode and grid respectively, the ratio of said capacities determining the extent of said regeneration, and means deriving a biasing voltage from said source of heterodyne oscillations for varying said regeneration inversely to changes in the oscillation amplitude, said capacities being proportioned to maintain the modulated output substantially

constant for relatively wide variations in the oscillation amplitude.

12. In a heterodyne signaling system including a signal modulator and a source of heterodyne oscillations subject to variations in amplitude, the method of compensating effects of said variations on the modulated signals which comprises,

regeneratively amplifying the modulated signals, deriving from said heterodyne oscillations a biasing voltage varying with the amplitude thereof, and utilizing said biasing voltage to regulate the regenerative amplification inversely to the oscillation amplitude.

NELSON P. CASE.