

Jan. 9, 1940.

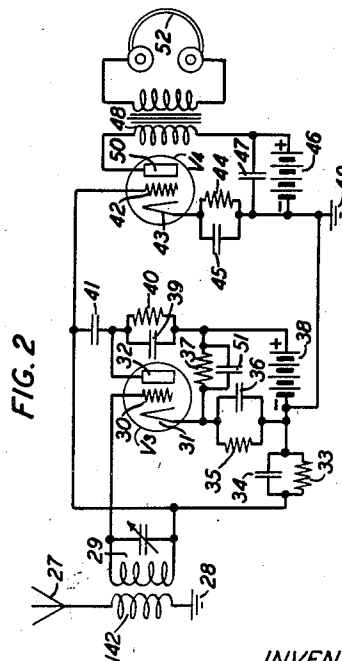
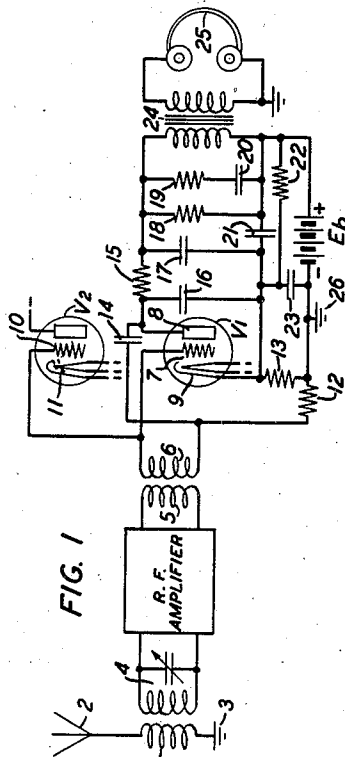
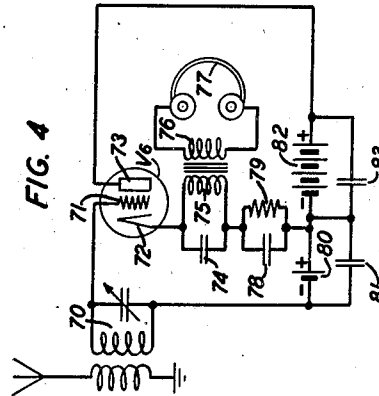
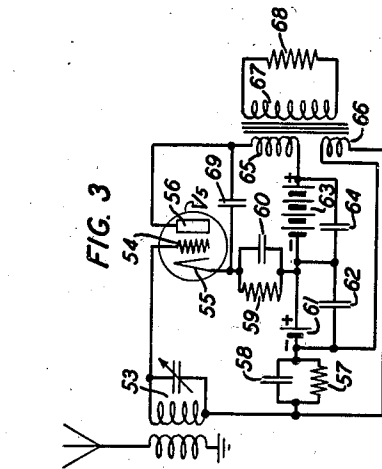
W. T. WINTRINGHAM

2,186,130

DETECTING SYSTEM

Filed Aug. 19, 1936

2 Sheets-Sheet 1



INVENTOR
W. T. WINTRINGHAM
BY *G. H. Stevenson*

ATTORNEY.

Jan. 9, 1940.

W. T. WINTRINGHAM

2,186,130

DETECTING SYSTEM

Filed Aug. 19, 1936

2 Sheets-Sheet 2

FIG. 5

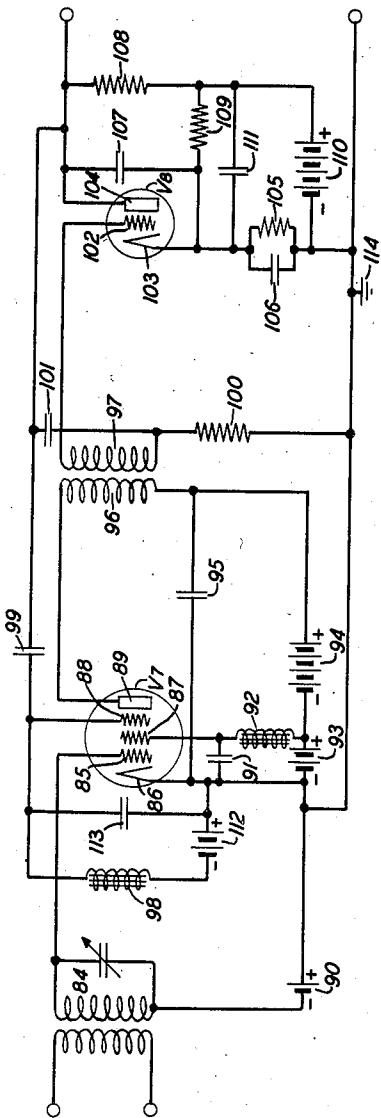
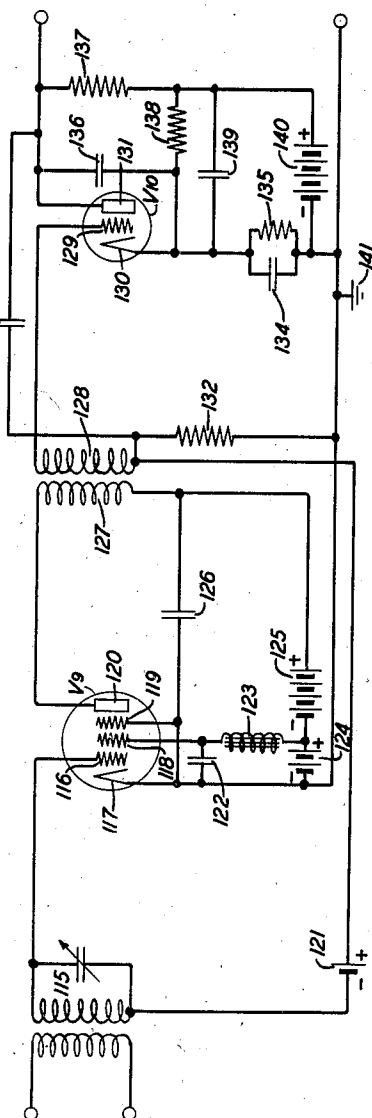


FIG. 6



INVENTOR
W. T. WINTRINGHAM
BY *G. H. Stevenson*
ATTORNEY

UNITED STATES PATENT OFFICE

2,186,130

DETECTING SYSTEM

William T. Wintringham, Chatham, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application August 19, 1936, Serial No. 96,774

19 Claims. (Cl. 250—27)

The invention relates to a detector of modulated waves and more particularly to a detecting system employing a vacuum tube.

An object of the invention is to improve the fidelity of reproduction of the envelope form of the modulated wave.

Another object is to improve the sensitivity of a vacuum tube detector without sacrificing fidelity of reproduction of the envelope form.

A particular object is to combine the beneficial effects of a negative grid bias to prevent absorption of energy by the tube from the incoming modulated wave with a negative or degenerative feedback connection selective to detected signal currents to minimize the distortion of the detected signal currents.

When a carrier wave of constant frequency and amplitude is amplitude-modulated by a signaling wave, the envelope of the modulated wave is a faithful reproduction of the signaling wave if there is no distortion in the modulation process. Since detection of a modulated wave is the process of obtaining a replica of the original signaling wave from the modulated wave, a condition for detection without distortion is that the detected wave be a reproduction of the envelope of the modulated wave. If the modulated wave were applied to a particular kind of ideal circuit element, the current through which is directly proportional to the high frequency voltage, whenever this voltage is positive and the current zero whenever the voltage is negative, the average current would be an exact replica of the envelope of the higher frequency wave. Even if such an ideal circuit element existed, stray reactances in circuits connected to it in any practical case would so alter the potentials across it that distortionless detection would not be produced.

Since impedances external to an apparently ideal detector element affect the operation of such a device as a detector, a fruitful mode of attack of the problem of distortionless detection lies in controlling the effect that these impedances have upon detection. If a circuit element which is conductive when the voltage across it is positive and non-conductive when the voltage is negative is connected in series with a source of modulated waves and a resistance which is very large compared to the resistance of the circuit element in the conducting condition, substantially all of the applied voltage will appear across the resistance during the positive half cycles and substantially all of the voltage drop in the circuit will take place across the non-linear circuit element during the negative half cycle.

The average voltage across either the resistance or the non-linear circuit element is a replica of the envelope of the impressed modulated wave; i. e., such a circuit approaches the ideal performance of a distortionless detector.

The averaging mentioned in the previous paragraph implies energy storage from cycle to cycle of the high frequency wave. If such energy storage takes place within the detector circuit, i. e., if the voltage to be averaged is not first transferred through a one-way device to the averaging means, the operation of the detector becomes quite different from that described, but the performance is not changed to any appreciable degree. A suitable means for energy storage and consequent averaging is a condenser connected in parallel with the external resistance in the detector circuit. To avoid discrimination against the higher modulation frequencies the magnitudes of the resistance and of the capacitance should be small. To minimize the distortion arising in detection, the resistance should be large, and to obtain the most effective averaging the capacitance should be large. It is seen that the dimensions of the resistor and capacitor used for this type of detector in any practical case represent a compromise.

When the detector circuit includes a condenser for averaging the voltage drop across the resistance, this voltage drop is only slightly different during the portions of the radio frequency cycle when the non-linear circuit element is conducting and non-conducting, respectively. The magnitude of the current through the non-linear circuit element during the conducting portion of the cycle is only that which is sufficient to maintain the charge on the condenser. As the effective resistance of the non-linear circuit element during the conducting cycle is made smaller, the portion of the cycle during which current must flow to maintain this charge is decreased with the consequence that the shape of the effective resistance-voltage characteristic of the non-linear circuit element has a lessened effect upon the voltage across the external resistance. When the detected wave is modulated, the identity between the voltage across the external resistance and the envelope of the modulated wave depends upon reducing this interval of current flow to a minimum. This effect can be obtained by increasing the voltage of the modulated carrier wave applied to the detector circuit as a whole; by increasing the value of the external resistance; or by increasing the capacitance of the shunt condenser.

A two or three electrode vacuum tube is frequently used as the non-linear circuit element for detection in circuits of the type just described. With the grid and plate elements of a triode connected together and used as one electrode and the cathode as the other, the equivalent of the usual diode detector results. With reasonable values of external resistance and capacitance, and large carrier voltages, the distortion arising in detection may be decreased to within quite satisfactory limits. The introduction of a modulated carrier voltage wave into such a detector circuit presents difficulties however, requiring, in general, the use of a radio frequency transformer the impedance of which is considerable. Such an impedance in series with the detector element not only gives rise to a reduction in voltage applied to the detector element, but likewise the distortion is changed from the value it would have with low carrier-frequency impedance in the circuit. To avoid these difficulties, the three electrode tube has been used as a plate circuit detector, where the grid is polarized negatively with respect to the cathode and operates as a control electrode only. Use is made of the plate-voltage plate-current characteristic of the tube in this type of detector. It has the advantage that the carrier frequency impedance in series with the detector element may be made as small as is desired; but the equivalent resistance of the plate-cathode circuit of the tube used in this manner is many times greater than the equivalent resistance of the circuit within the tube between the anode and grid in parallel and the cathode when the tube is used as a diode detector. It is difficult therefore to make use of external impedances sufficiently large to control the detection in the plate detector case, and as a consequence the distortion in this type of detector is excessive.

The detecting arrangement of the present invention, working on the feedback principle, combines the advantages of both earlier types of detector. Since voltages applied to the grid electrode of a triode are more effective than voltages applied to the plate electrode in changing the plate current (in the ratio of the amplification factor of the tube) the voltages appearing across a resistance-condenser combination in the plate circuit of a triode can be made much more effective by feeding them back to the grid circuit.

The invention may be more fully understood from the following detailed description thereof, together with the accompanying drawings.

In Fig. 1, there is shown an application of a feedback detector in a radio receiver.

Fig. 2 illustrates one method of connecting a signal amplifier to the feedback detector.

Alternate circuits for producing feedback are shown in Figs. 3 and 4.

The circuits shown in Figs. 5 and 6 illustrate how the feedback may be extended to be operative on a radio-frequency amplifier preceding the detector, as well as upon the detector.

Referring to Fig. 1, the primary coil 1 of the input circuit of a radio receiver is connected between an antenna 2, and a ground 3. Inductively coupled to coil 1 is a tuned circuit 4, the voltage across which is applied to the input terminals of a radio-frequency amplifier. The output terminals of this amplifier are connected to the primary winding 5 of a radio-frequency transformer. One terminal of the secondary winding 6 of this transformer is connected in multiple to the grid 7 of a three-element vacuum

tube V_1 and to the grid 10 of a three-element vacuum tube V_2 . The other terminal of winding 6 is connected through a condenser 14 to anode 8 of triode V_1 , and through a resistance 12 to a common ground connection 26. The cathode 9 of the triode V_1 is connected to ground 26 by the parallel combination of a resistance 13 and a condenser 23. The connections to the remaining electrodes of the triode V_2 , including the return path from the cathode 11 to ground 26, are not shown, as they are not considered essential to the invention and can readily be supplied by one skilled in the art of radio reception. The anode 8 is connected to the cathode 9 by a radio-frequency by-pass condenser 16. A resistance 15 is connected between the anode 8 and one terminal of the primary winding of a signal output transformer 24. A condenser 21 is connected between the other terminal of the primary winding of the signal output transformer 24 and the cathode 9. A resistance 18, in parallel with a series circuit consisting of a resistance 19 and a condenser 20 is connected also across the primary winding of the transformer 24. A condenser 17 is connected between the junction of the resistance 15 and the primary winding of transformer 24, and the cathode 9 of the triode V_1 . A battery E_b is connected between ground 26 and the junction of the condenser 21 and the primary winding of the transformer 24, the negative end of this battery being connected to ground. A resistance 22 is connected between the positive end of the battery E_b and the cathode 9. The telephone receivers 25 (or other signal responsive means) are connected to the terminals of the secondary winding of transformer 24.

In the operation of the system of Fig. 1, modulated radio signals are intercepted by means of antenna 1 and are selected and amplified in the conventional manner in the apparatus preceding the vacuum tubes V_1 and V_2 . In the absence of a signal, the direct current from battery E_b through resistances 13 and 22 is so adjusted that the drop in potential across resistance 13 is of the proper value to reduce the space current of V_1 substantially to zero, or to an optimum value near zero. Upon the reception of an unmodulated carrier wave, plate circuit detection takes place in triode V_1 , with the result that the space current of this tube tends to increase. Such an increase in space current increases the steady potential across resistance 13 however, with the result that the relative grid-cathode potential of V_1 is increased in the negative direction. Such an increase of negative grid potential tends to decrease the space current over the value it had in the absence of this direct current feedback. The net result of these two tendencies is the establishment of a new value of steady voltage drop across resistance 13, somewhat greater than the value in the absence of the unmodulated carrier wave. When this wave is modulated with a signal wave, a similar balancing takes place, but in a different manner. The by-pass condenser 23 is sufficiently large that the voltage across resistance 13 is substantially unaltered by the signaling currents flowing in the anode circuit of triode V_1 , with the result that the cathode 9 is practically at ground potential for signaling currents. The anode load circuit, made up of resistances 15, 18 and 19, condensers 17 and 20 and output transformer 24, is proportioned, however, in such a way that it offers impedance to currents of the frequencies of the signal wave. As a

consequence, signal frequency currents flowing in the anode circuit of V_1 as a result of detection of the modulated carrier wave, produce voltages of the same frequencies between the anode and cathode of triode V_1 . By making condenser 14 sufficiently large, practically identical voltages will also appear across resistance 12. Voltages of the signaling frequencies across resistance 12 produce variations of the grid-cathode potential, and these variations are in such direction that upon amplification in the triode they tend to reduce the amplitude of the signal wave components in the anode circuit. If the detected wave in the anode circuit contains distortion components introduced in the detection process, these components are reduced by the feedback action to a greater extent than are those components which are present in the envelope of the incoming modulated wave. It has been found that the distortion at the output of a triode tube used as a plate circuit detector is reduced appreciably when this feed-back action is applied.

The signal frequency components of the anode current flow from the anode 8 through the resistance 15, the parallel circuit consisting of resistances 18 and 19 and condensers 17, 20 and 21, and the primary winding of signal output transformer 24 to the cathode 9. As is well-known in the art, the relative magnitudes of the various resistances and condensers and the impedance presented by the primary winding of the output transformer determine the ratio of the current flowing through this primary winding to the total anode current, at each frequency in the signal frequency band. Discrimination against or accentuation of certain signaling frequency components in the radio-frequency amplifier may be corrected by adjustment of this division of current. The portion of the anode signal current flowing through the primary winding of the signal output transformer 24 induces corresponding voltages in the secondary circuit and the currents corresponding to these induced voltages actuate the telephone receiver 25.

Vacuum tube V_2 , grid 10 of which is connected in parallel with grid 7 of vacuum tube V_1 is included to indicate a suitable way in which a detector for automatic gain control may be connected. As pointed out above, the potential difference between grid 7 or grid 10 and ground is made up of two parts: the modulated carrier wave which appears across the secondary 6 of the radio-frequency transformer, and the signaling wave fed back from the anode circuit of triode V_1 and which appears across resistance 12. These two waves are so poled that when the envelope of the modulated wave increases in amplitude, the fed-back signaling wave tends to keep the total positive excursion of grids 7 and 10 relative to ground constant.

Referring to Fig. 2, the primary 142 of a radio frequency transformer is connected between an antenna 27 and a ground 28, and is inductively coupled to a tuned secondary circuit 29. One side of the tuned circuit 29 is connected to the grid electrode 30 of a triode V_3 which is used as a feedback detector, and the other side of the tuned circuit 29 is connected through the parallel combination of a resistance 33 and a radio-frequency by-pass condenser 34 to ground 49. This latter terminal of tuned circuit 29 is connected also through a signal feedback condenser 41 to the anode 32 of a triode V_3 and a fourth connection is made to the control electrode 42 of a signal amplifier triode V_4 . The cathode 31 of the triode

V_3 is connected to a ground 49 through the parallel combination of a biasing resistance 35 and a by-pass condenser 36. The anode 32 of the triode V_3 is connected to the cathode 31 of this same tube by two parallel circuits connected in series. One of the parallel circuits comprises an anode load resistance 40 and a radio-frequency by-pass condenser 39, and the other parallel circuit consists of an initial bias resistance 37 and a large by-pass condenser 51. The positive terminal of a plate battery 38 is connected to the common connection between these two parallel circuits, and the negative terminal of this battery is connected to ground 49. The cathode 43 of the signal amplifier triode V_4 is connected to ground 49 through the parallel combination of a biasing resistance 44 and a by-pass condenser 45. A plate battery 46 is connected to anode 50 of triode V_4 through the primary winding of a signal output transformer 48 and is shunted by a by-pass condenser 47. The secondary winding of the output transformer 48 is connected to the telephone receivers 52 or to other signal responsive means.

The circuit in Fig. 2, while intended primarily to show a simplified method of connecting a signal amplifier to the output of a feedback detector, serves to indicate more clearly than does the circuit in Fig. 1 some of the features of the feedback detector. In particular, condenser 34 is included to indicate that the radio-frequency potential across resistance 33 is reduced to as small a value as possible; the condenser being kept sufficiently small that its reactance at signal frequencies is large compared to the resistance 33. Across resistance 33, therefore, only signal frequency voltages exist to any appreciable degree. Similarly across resistance 40, radio-frequency voltages are reduced, while both signal frequency and zero frequency voltages predominate. Due to the presence of by-pass condenser 36, the principal voltage across resistance 35 is direct current, although it is unavoidable that some small signal frequency and radio-frequency potentials will likewise be built up across this circuit between cathode 31 and ground 49. Condenser 41 is chosen of such size in relation to resistances 33 and 40 that so far as signal frequencies are concerned, these two resistances are effectively in parallel and the same signal frequency voltages appear across both resistances. The grid cathode bias of triode V_3 is adjusted in the absence of signal to a value near to space current cut-off, by adjustment of the value of resistances 35 and 37 in conjunction with the voltage of battery 38. Under this condition, the change in space current of V_3 produced by the application of an unmodulated radio-frequency carrier increases the direct current voltage drop across biasing resistance 35. This increase in negative grid-cathode bias is such that space current flows only during the small portion of the positive half of each radio-frequency cycle, i.e., the new bias is very near to space current cut-off. When the radio-frequency carrier is modulated, a further change in space current takes place, this change being largely at the frequencies of the modulating signal. This change in space current at the modulation rate produces voltages varying at the same rate across resistances 33 and 40. The effect of the voltage drop across resistance 40 upon the operation of the detector is small, in general, but the voltage drop across resistance 33 adds directly to the negative grid-cathode bias already existing in the circuit. The polarity of these vol-

tage variations across resistance 33 is again such that the total grid-cathode bias varies with variation in the carrier amplitude during the modulation cycle in the proper direction that the space current flows only during a small portion of each positive half cycle of the high frequency wave. The signal frequency amplifier triode V_4 is self-biased in the usual manner by the drop in potential due to its own space current flowing through biasing resistance 44. As pointed out above, the voltages across resistance 33 are practically the same as the voltages corresponding to the signal wave across resistance 49. Instead of coupling the control grid of triode V_4 by means of a condenser to resistance 49, and adding a grid leak to apply negative bias to this electrode, condenser 41 and resistance 33 serve a double purpose and replace these customary elements. The remainder of this circuit operates in the usual manner.

The circuit shown in Fig. 3 is an illustration of the use of inductive feedback coupling at signal frequencies between the anode and grid circuits of the detector instead of the use of capacity-resistance coupling shown in Figs. 1 and 2. One terminal of the secondary of a tuned radio-frequency transformer 53 is connected to the control grid 54 of a three electrode vacuum tube V_5 . The other terminal of the secondary of transformer 53 is connected through the parallel combination of a radio-frequency by-pass condenser 52 and a resistance 57, which is shunted by the tertiary winding 66 of a signal frequency output transformer, to a grid biasing battery 61. This biasing battery is shunted by a by-pass condenser 62. A biasing resistance 59 shunted by a by-pass condenser 60 is connected between this biasing battery and the cathode 55 of triode V_5 . The anode 56 of triode V_5 is connected to one terminal of a radio-frequency by-pass condenser 69, the other terminal of which is connected to the cathode 55 of triode V_5 . The anode 56 is connected also to one terminal of a primary winding 65 of the signal output transformer. The other terminal of the primary winding 65 is connected to the positive terminal of a plate battery 33. The negative terminal of this battery is connected to the common connection between the grid biasing battery 61 and the biasing resistance 59. The plate battery 33 is shunted by a large by-pass condenser 64. The secondary winding 67 of the signal frequency output transformer is connected to a load circuit, illustrated by a resistance 68.

In the absence of any signal, batteries 61 and 33 are adjusted to such voltages that the space current of triode V_5 is practically zero. Upon the reception of an unmodulated carrier, the change in steady anode current through triode V_5 produces an increase in the potential drop across resistance 59. This increase in negative grid-cathode biasing potential produces a shift in the operating point so that the anode current is reduced from the value it would have without this direct current feedback, but only to a value slightly larger than it had in the absence of the unmodulated carrier. When the received carrier wave is modulated, the component of the anode current corresponding to the modulation flows through primary winding 65 of the output transformer, and by induction a corresponding voltage is produced in tertiary winding 66. The voltage in the tertiary winding causes current to flow in the series circuit consisting of the tertiary winding and resistance 57, with the result

that voltages corresponding to the modulating wave components of the anode current appear across resistance 57. By properly poling windings 65 and 66, the voltage across resistance 57 will be of such phase as to increase the negative bias on the control grid 54 of triode V_5 relative to cathode 55 when the envelope of the modulated wave increases in the positive sense. This circuit operates, therefore, to reduce the distortion of the modulation-wave-form arising from detection in the same manner as the circuits shown in Figs. 1 and 2.

The circuit shown in Fig. 4 represents a further variation inasmuch as direct feedback coupling from the anode circuit to the grid circuit is accomplished by utilizing feedback circuit elements common to both circuits. In this circuit, the grid electrode 71 of a three-element vacuum tube V_6 is connected to one terminal of the tuned secondary circuit 70 of a radio-frequency transformer. The cathode 72 of triode V_6 is connected through the parallel combination of a radio-frequency by-pass condenser 74 and a signal frequency output transformer primary winding 75 and through the parallel combination of a by-pass condenser 78 and a biasing resistance 79 to the common connection of the plate and the grid batteries. A grid bias battery 80 is shunted by a by-pass condenser 81, and a plate battery 82 is shunted by a by-pass condenser 83.

In the circuit shown in Fig. 4, the initial adjustment of the space current almost to zero is made by varying the relative potentials of batteries 80 and 82. Rectified space current flowing when an unmodulated carrier is received, produces a steady increment in the negative grid-cathode bias by means of the drop in potential across resistance 79. When the received carrier is modulated, detected signal frequency components of the anode current flowing through the primary winding 75 of the signal frequency output transformer produce signal frequency voltages across this winding. Since these voltages are produced within the grid-cathode circuit, the effective grid-cathode bias is varied at the modulation rate. Exactly as in the previous cases, the polarity of these feedback voltages is such that space current flows only during a small part of each positive half cycle of the modulated radio-frequency wave.

Referring to Fig. 5, a method is illustrated for feeding back the signaling wave, not only to the input of a detector, but also to the tubes in a radio-frequency amplifier preceding the detector. One terminal of the secondary of a radio-frequency transformer 84 is connected to the control electrode 85 of a five-element vacuum tube V_7 . The other terminal of the secondary 84 is connected through a grid bias battery 90 to the cathode 86 of pentode V_7 . A large by-pass condenser 91 is connected between the screen electrode 87 and the cathode 86 of pentode V_7 . The screen 87 is connected also to one terminal of choke coil 92, the other terminal of which is connected to the positive terminal of a battery 93. The negative terminal of the battery 93 is connected to the cathode 86 of the pentode V_7 . The suppressor grid electrode 88 of the pentode V_7 is connected to one terminal of choke coil 93, the other terminal of which is connected to the negative terminal of a battery 112. The positive terminal of the battery 112 is connected to cathode 86 of the pentode V_7 . A radio-frequency by-pass condenser 113 is connected between the suppressor grid electrode 88 and the cathode 86 of

the pentode V_7 . The suppressor grid electrode 88 is connected also through a signal feedback condenser 99 to the anode electrode 104 of a triode tube V_8 . The anode electrode 89 of the pentode V_7 is connected to one terminal of a primary winding 96 of a radio-frequency transformer. The other terminal of the primary winding 96 is connected both to one terminal of a large by-pass condenser 95, the other terminal of which is connected to the cathode 86 of the pentode V_7 , and to the positive terminal of a battery 94. The negative terminal of the battery 94 is connected to the positive terminal of the battery 93. The circuits connected to the secondary winding 97 of the radio-frequency transformer may be those of any detector. The preferred form chosen for representation in Fig. 5 is an improved feedback type of detector of the same type illustrated in Fig. 2. In Fig. 5, V_8 is a detector triode, the grid 102 of which is connected to one terminal of the secondary winding 97. The other terminal of the winding 97 is connected through a signal feedback condenser 101 to the anode 104, and also through a resistance 100 to ground 114. The cathode 103 is connected to ground 114 through the parallel combination of a by-pass condenser 106 and a bias resistance 105. The radio-frequency by-pass condenser 107 is connected between the anode 104 and the cathode 103 of the triode V_8 . One terminal of a resistance 108 is also connected to the anode 104 the other terminal of this resistance being connected to one terminal of an initial bias resistance 109, one terminal of a large by-pass condenser 111, and the positive terminal of a plate battery 110. The other terminals of the resistance 109 and the condenser 111 are connected to the cathode 103 of triode V_8 . The negative terminal of the plate battery 110 is connected to ground 114. Additional signal responsive means may be connected between anode 104 of triode V_8 and ground 114.

In the absence of the signal feedback condenser 99, the operation of the amplifier-detector shown in Fig. 5 would be precisely what would be expected from a conventional radio frequency amplifier followed by a feedback detector of the sort described above. A well-known property of a pentode tube containing a suppressor grid in a radio frequency amplifier is the change in gain of such an amplifier when the potential difference between suppressor-grid and cathode is varied. If the tube is operating as an amplifier of a radio frequency wave and a signaling voltage is applied to the suppressor grid, the output wave from the amplifier will be modulated by the signal wave. It is this property of the suppressor grid pentode of which use is made in the circuit shown in Fig. 5. If the modulation index of a modulated wave be defined as the ratio of half the difference between the maximum and minimum amplitudes of the modulated wave to the average amplitude, the distortion of the signaling wave due to detection of a modulated wave with a conventional detector is greatest when the modulation index has its maximum value. The feedback detector here disclosed tends to reduce this distortion by a balancing action. The feedback amplifier circuit shown in Fig. 5 represents one method of reducing this distortion still further by modulating the modulated wave with the signaling wave in a reverse sense so that the modulation index at the input to the detector is reduced. This remodulation of the received modulated

wave is carried out by applying the output signal wave from the detector to the suppressor grid 88 of pentode V_1 in Fig. 5 through the coupling condenser 99. During the portion of the modulation cycle when the amplitude of the modulated wave at the grid 102 of the triode V_8 is increasing, the anode current of this tube increases also. The potential of the anode 104 relative to ground 114 is equal to the sum of the electromotive force of the battery 110 and the voltage drop across the resistance 108 for frequencies sufficiently low that the reactance of the condenser 107 is much larger than the value of the resistance 108. Where the anode current increases at the signaling rate the voltage drop across the resistance increases at the same rate and, therefore, the potential difference between the anode 104 and ground 114 decreases at the same rate. A decrease in positive potential is equivalent to an increase in negative potential, so it may be said that as the envelope of the wave at grid 102 increases in magnitude, the anode potential tends to increase in a negative direction. By means of coupling condenser 99 this increasing negative potential is applied to suppressor grid 88 of pentode V_7 . Cathode 86 is at the same signal potential as ground 114, so that the suppressor-grid to cathode potential of pentode V_7 is made increasingly negative. Such an increase in suppressor-grid negative potential decreases the gain of the amplifier stage of which pentode V_7 is a part, with the result that the amplitude of the modulated wave at grid 102 of detector triode V_8 is decreased. Similarly, during the part of the modulation cycle when the amplitude of the received wave is decreased, the gain of this amplifier stage is increased, and the amplitude of the wave at grid 102 is increased. Effectively then the modulation index of the received wave has been decreased, with a corresponding desirable effect upon the distortion produced in the detector. Obviously this control action may be extended over as many stages of a radio frequency amplifier as may seem desirable.

The circuit shown in Fig. 6 represents a modification of that shown in Fig. 5. In this case modulation in the radio-frequency amplifier is effected by using the control grid electrode of the pentode instead of the suppressor grid electrode. One terminal of a radio-frequency transformer secondary 115 is connected to the control grid 116 of a pentode V_9 . The other terminal of the secondary winding 115 is connected through a grid biasing battery 121 to the junction between a feedback condenser 133 and a feedback resistance 132. A large by-pass condenser 122 is connected between the screen electrode 118 and the cathode 117. The screen 118 is connected also to one terminal of a choke coil 123, the other terminal of which is connected to the positive terminal of a battery 124. The negative terminal of the battery 124 is connected to the cathode 117 of the pentode V_9 . The suppressor-grid electrode 119 of the pentode V_9 is connected directly to the cathode 117. One terminal of a primary winding 127 of a radio-frequency transformer is connected to the anode 120 of the pentode V_9 . The other terminal of the primary winding 127 is connected both to one terminal of a large by-pass condenser 126 and to the positive terminal of a battery 125. The other terminal of the by-pass condenser 126 is connected to the cathode 117. The negative terminal of the battery 125 is connected to the

positive terminal of the battery 124. The circuit beyond the secondary winding 128 of the radio-frequency transformer is identical to the detector circuit shown in Fig. 5, except for the omission of the feedback condenser 33.

As is well known in the art, modulation may be effected in practically any vacuum tube containing a control grid by applying carrier and modulation voltage in series with an appropriate direct current bias between the control grid and cathode of that tube. In the circuit shown in Fig. 6, radio-frequency voltages are produced across the secondary winding 115, direct current bias is supplied by the battery 121, and when the received wave is modulated, signal frequency voltages appear across the resistance 132, due to feedback in the detector stage. This circuit therefore, is suitable for making use of pentode V_9 as a modulator. As has been explained in connection with the feedback detector circuits shown in Figs. 1 and 2, due to the presence of feedback condenser 133, the signal frequency voltages across resistance 132 are practically the same as those across resistance 137. When, due to modulation, the radio frequency voltage applied to grid 129 of triode V_{10} increases, the potential above ground 141 of the junction between resistance 132 and secondary winding 128 becomes increasingly negative at the modulation rate. This increasingly negative potential is applied to grid 116 of pentode V_9 , with the result that the gain of the amplifier stage including pentode V_9 is decreased. Such decreased gain results in a decrease of the amplitude of the radio-frequency wave at grid 129 of triode V_{10} . Similarly, when the radio-frequency potential at grid 129 decreases due to modulation, the gain of the amplifier stage including pentode V_9 is increased, increasing the amplitude of the wave at grid 129. The net result of this remodulation of the original modulated wave is a decrease in the modulation index of the wave applied to the detector, with a consequent decrease in distortion arising in detection.

What is claimed is:

1. A detecting system comprising a space discharge device having a cathode, an anode and a control grid, a source of signal modulated carrier waves connected to the grid circuit of said space discharge device, means for biasing the grid to a negative potential sufficient to prevent the flow of grid current during normal operation, and a resistive load selectively coupled at signal frequencies both to the grid circuit and to the anode circuit in such relation to each that a change of potential across the load has compensatory effects upon said two circuits.

2. A detecting system comprising a space discharge device having a cathode, an anode and a control grid, a source of signal modulated carrier waves connected to the grid circuit of said space discharge device, negative biasing means for preventing the flow of grid current, a resistance coupled to the anode circuit, and lying in a path traversed by detected signal currents, and coupling means for selectively transferring signal variations from said resistance into the grid circuit, in phase opposition to the envelope variations of the signal modulated carrier waves impressed in said circuit.

3. A detecting system comprising a space discharge device having a cathode, an anode and a control grid, a source of signal modulated carrier waves connected to the grid circuit of said space discharge device, negative biasing means for pre-

venting the flow of grid current, and a resistive load selectively coupled at signal frequencies both to the grid circuit and to the anode circuit, the couplings being so poled respectively that a change of potential in the load affects both the grid and anode potentials in such direction as to counteract said potential change in the load.

4. A detecting system comprising a space discharge device having a cathode, an anode and a control grid, a source of modulated carrier waves connected to the grid circuit of said space discharge device, a source of negative biasing potential connected to the grid, and a resistive load selectively coupled at signal frequencies both to the grid circuit and to the anode circuit in such relation to each that a change of potential across the load has compensatory effects upon said two circuits.

5. A detecting system comprising a space discharge device having a cathode, an anode and a control grid, a source of signal modulated carrier waves connected to the grid circuit of said space discharge device, means for biasing the grid to a negative potential sufficient to prevent the flow of grid current during normal operation, and a resistance of large value relatively to the plate cathode resistance of the tube, said resistance being selectively coupled at signal frequencies both to the grid circuit and to the anode circuit in such relation to each that a change of potential across the load has compensatory effects upon said two circuits.

6. A detecting system comprising a space discharge device having a cathode, an anode and a control grid, a source of signal modulated carrier waves connected to the grid circuit of said space discharge device, means for biasing the grid to a negative potential sufficient to prevent the flow of grid current during normal operation, and a resistive load selectively coupled by conductive coupling at signal frequencies both to the grid circuit and to the anode circuit in such relation to each that a change of potential across the load has compensatory effects upon said two circuits.

7. A detecting system comprising a space discharge device having a cathode, an anode and a control grid, a source of signal modulated carrier waves connected to the grid circuit of said space discharge device, means for biasing the grid to a negative potential sufficient to prevent the flow of grid current during normal operation, and a resistive load coupled by capacitive coupling at signal frequencies both to the grid circuit and to the anode circuit in such relationship to each that a change of potential across the load has compensatory effects upon said two circuits.

8. A detecting system comprising a space discharge device having a cathode, an anode and a control grid, a source of signal modulated carrier waves connected to the grid circuit of said space discharge device, means for biasing the grid to a negative potential sufficient to prevent the flow of grid current during normal operation, and a resistive load selectively coupled by inductive coupling at signal frequencies both to the grid circuit and to the anode circuit in such relation to each that a change of potential across the load has compensatory effects upon said two circuits.

9. In a wave transmission system, the method of operating upon a modulated carrier wave which comprises amplifying said wave in an electron discharge device having a cathode, anode, control grid, screen grid and an auxiliary grid between said screen grid and said anode, apply-

ing the output of said device to the input of a second electron discharge device, rectifying said wave in the latter device to produce the modulating signal wave in the output of said second device, feeding back a portion of said rectified output across the cathode and the auxiliary grid of the first discharge device, and modulating the modulated carrier wave in accordance with the feedback wave.

10. A wave transmission system comprising modulated carrier wave amplifying means including an electron discharge device having a cathode, an anode, a control grid, a screen grid and a third grid, the latter grid being positioned between said screen grid and the anode and connected to said cathode, means for rectifying the amplified output of said amplifying means, and means for feeding back to said third grid a portion of the rectified output wave of said rectifying means so that said feedback wave modulates the modulated carrier wave in sense opposite to that in which the carrier wave is initially modulated.

11. A wave transmission system comprising an electron discharge device having a cathode, an anode, a control grid, a screen grid, and a third grid positioned between the screen grid and the anode and connected to said cathode, means for biasing said third grid to a potential negative with respect to the cathode, means for impressing a modulated carrier wave between said control grid and cathode, a second electron discharge device having a cathode, an anode and a control grid, means coupling the anode-cathode circuit of said first device with the grid-cathode circuit of said second device, and means for feeding back to the grid-cathode circuit of said second device and to the third grid-cathode circuit of said first device a portion of the energy in the cathode-anode circuit of said second device.

12. A wave transmission system comprising an amplifying electron discharge device having a cathode, an anode, a control grid, a screen grid, and a third grid positioned between the screen grid and the anode and connected to said cathode, means for biasing said third grid to a potential negative with respect to the cathode, means for impressing a modulated carrier wave between said control grid and cathode, a rectifying electron discharge device having a cathode, an anode and a control grid, means coupling the anode-cathode circuit of said first device with the grid-cathode circuit of said second device, and means for feeding back to the grid-cathode circuit of said second device and to the third grid-cathode circuit of said first device a portion of the energy in the cathode-anode circuit of said second device.

13. A wave transmission system comprising an amplifying electron discharge device having a cathode, an anode, a control grid, a screen grid, and a third grid positioned between the screen grid and the anode and connected to said cathode, means for biasing said third grid to a potential negative with respect to the cathode, means for impressing a modulated carrier wave between said control grid and cathode, a rectifying electron discharge device having a cathode, an anode and a control grid, means coupling the anode-cathode circuit of said first device with the grid-cathode circuit of said second device, and means for feeding back to the grid-cathode circuit of said second device and to the third grid-cathode circuit of said first device a portion of the energy in the cathode-anode circuit of said

second device, said means comprising a resistance in the grid-cathode circuit of the second device and a capacity connecting the resistance with the anode of said second device, and a capacity connecting the third grid of the first device and the anode of said second device.

14. A wave transmission system comprising an electron discharge device having a cathode, an anode, a control grid, a screen grid and a third grid positioned between said screen grid and said anode, means for impressing a modulated carrier wave between said control grid and cathode, a second electron discharge device having a cathode, an anode and a control grid, impedance means coupling the cathode-anode circuit of said first device with the control grid-cathode circuit of said second device, and means for feeding back to the grid-cathode circuit of said second device and to a grid-cathode circuit of said first device a portion of the energy in the cathode-anode circuit of said second device.

15. In combination, an electron discharge device comprising a cathode, an anode and a grid, means for impressing electric wave energy between said cathode and grid, a resistor connected to said cathode and common to the grid-cathode and the cathode-anode circuits of said device, a source of direct current potential for said anode, a local circuit including said resistor and said potential source for producing a potential drop in said resistor to bias the control grid negative with respect to the cathode, the space current of said device also producing a grid biasing negative potential drop, a second resistor connected between the low potential end of said cathode resistor and said grid, and means for impressing a portion of the energy in the anode-cathode circuit on said second resistor in pre-assigned phase relation to the electric wave energy impressed across said cathode and grid.

16. In combination, an electron discharge device comprising a cathode, an anode and a grid, means for impressing electric wave energy between said cathode and grid, a resistor connected to said cathode and common to the grid-cathode and the cathode-anode circuits of said device, a source of direct current potential for said anode, a local circuit including said resistor and said potential source for producing a potential drop in said resistor to bias the control grid negative with respect to the cathode, the space current of said device also producing a grid biasing negative potential drop, a second resistor connected between the low potential end of said cathode resistor and said grid, a second electron discharge device having a cathode, an anode and a grid, and means for impressing a portion of the energy in the anode-cathode circuit of the first device on said second resistor in preassigned phase relation to the electric wave energy impressed across the cathode and grid of the first device, and on the cathode-grid circuit of said second device.

17. In combination, an electron discharge device comprising a cathode, an anode and a grid, means for impressing electric wave energy between said cathode and grid, an impedance connected to said cathode and common to the grid-cathode and cathode-anode circuits, a source of potential for said anode, means independent of space current flow through said impedance for producing a potential drop in said impedance to bias the grid negative with respect to said cathode, a second impedance connected between the low potential end of said cathode impedance and said grid, and means for impressing a portion of

the energy in the cathode-anode circuit on said second impedance in preassigned phase relation to the electric wave energy impressed across said cathode and grid.

18. In combination, an electron discharge device comprising a cathode, an anode and a grid, means for impressing electric wave energy between said cathode and grid, an impedance connected to said cathode and common to the grid-cathode and cathode-anode circuits, a source of potential for said anode, means independent of space current flow through said impedance for producing a potential drop in said impedance to bias the grid negative with respect to said cathode, a second impedance connected between the low potential end of said cathode resistor and said grid, a second electron discharge device having a cathode, an anode and a grid, and means for impressing a portion of the energy in the anode-cathode circuit of said first device on said second impedance in preassigned phase relation to the electric wave energy impressed across the cathode and grid of the first device, and on the cathode-grid circuit of said second device.
19. A wave translating system comprising an

electron discharge device having a cathode, an anode and a grid, an impedance connected to the cathode and common to the grid-cathode and cathode-anode circuits, means for producing space current flow through said device, means including said impedance but not the space current path for biasing the grid substantially to space current cut-off, said impedance providing a grid bias of the same character on application of an unmodulated carrier wave across a pair of said electrodes to limit the space current resulting therefrom substantially to that for the initial grid bias condition, the resultant grid bias being such that, if the carrier wave has been modulated by a signal wave, space current flows for only a small part of each positive portion of the cycle of the modulated wave, an impedance connected between said grid and the end of said first impedance remote from the cathode, and means connecting the cathode-anode and the grid-cathode circuits for feeding back from the cathode-anode circuit to said second-mentioned impedance a portion of the signal wave energy in preassigned phase relation.

WILLIAM T. WINTRINGHAM.