

July 6, 1943.

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2,323,598

VARIABLE SIGNAL RESPONSE NETWORK

Filed Jan. 7, 1941

2 Sheets-Sheet 1

Fig. 1.

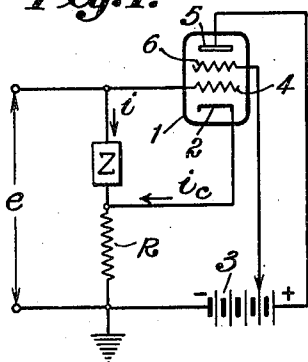


Fig. 2.

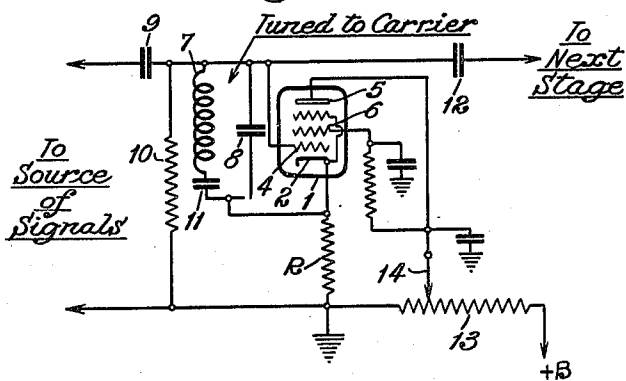


Fig. 3.

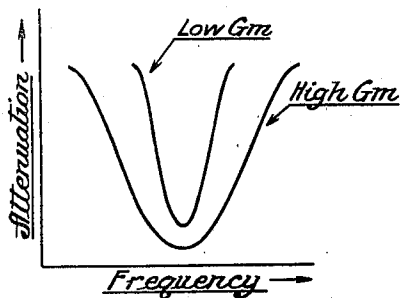


Fig. 4.

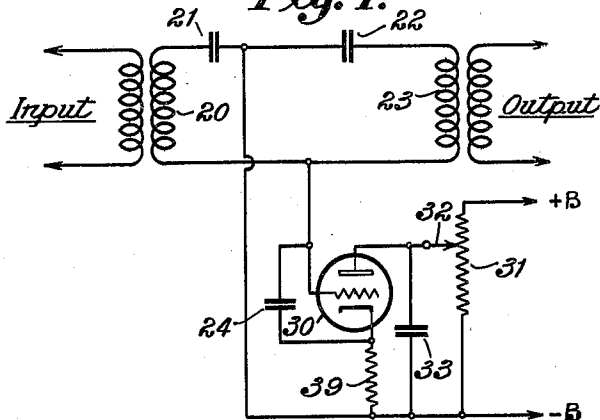
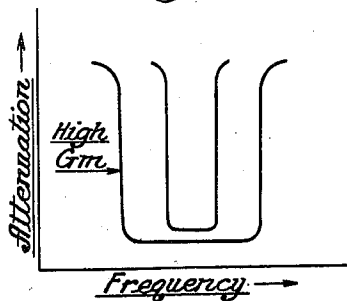


Fig. 5.



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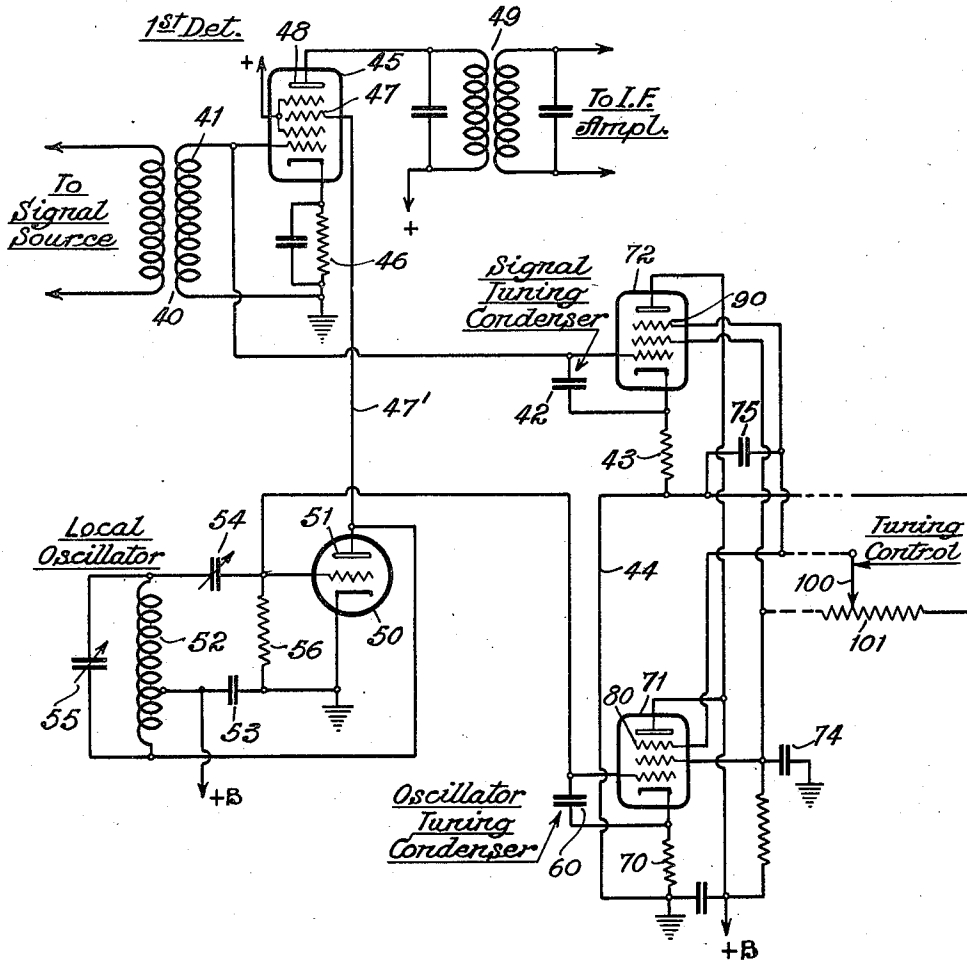
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VARIABLE SIGNAL RESPONSE NETWORK

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2 Sheets-Sheet 2

Fig. 6.



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VARIABLE SIGNAL RESPONSE NETWORK

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10 Claims. (Cl. 250—20)

My present invention relates to devices for adjusting the response characteristic of signal transmission circuits, and more particularly to a degenerative electronic device adapted to produce a variable impedance effect between its input terminals.

It has been previously shown that if an unby-passed resistor is inserted in the cathode circuit of an electron discharge tube, which resistor is common to the input and output electrodes, and an impedance is connected between the input electrodes while signals are applied to the signal control electrode, that variation of the gain of the tube results in a change in magnitude of the impedance. This has been considered an undesirable effect, particularly where the impedance was a tuned circuit of a degenerative amplifier. Further, many various arrangements have been previously proposed to adjust the response of a tuned circuit or the band pass characteristic of a band filter network.

Now, it is one of the main objects of my present invention to utilize the aforesaid previously considered undesirable effect in adjusting the response of a signal transmission circuit.

Another important object of the invention is to provide an electronic device of a degenerative type between whose input electrodes may be inserted a reactive impedance whose magnitude is varied by varying the gain of the electronic device, and the latter being free of any signal transmission function.

Another object of my invention is to provide an effective means for varying the common coupling reactance of a band pass network; the varying means comprising a tube of variable gain provided with a degenerating impedance in its cathode circuit, and the coupling reactance being included between the tube input electrodes.

Another object of my invention is to provide a signal receiver system wherein the aforementioned type of electronic device may be employed to adjust the frequency of the selector circuits over a relatively wide frequency range.

Another object of this invention is to provide a superheterodyne receiver wherein the signal and oscillator circuits may be conjointly controlled in frequency over a wide frequency range by means of electronically-controlled devices.

Still another object of my invention is to improve the tuning of an oscillator circuit; there being employed an electronic device of a degenerative type whose input electrodes have a reactive element therebetween whose value may

be adjusted by varying the device transconductance.

The novel features which I believe to be characteristic of my invention are set forth in particularity in the appended claims; the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description taken in connection with the drawings in which I have indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawings:

Fig. 1 schematically shows a circuit to explain the operation of the invention,

Fig. 2 shows one use of the circuit,

Fig. 3 graphically shows the effect of the invention in Fig. 2,

Fig. 4 illustrates the invention as applied to a band pass network,

Fig. 5 shows the effect of the adjusting device in the modification of Fig. 4,

Fig. 6 shows another modification.

Referring now to the accompanying drawings, and specifically to Fig. 1, there will first be presented the theoretical background of the invention. Assume a tube 1, which may be of the screen grid type, has its cathode 2 connected to the grounded terminal of direct current source 3 through an unby-passed resistor R. Between the signal grid 4 and cathode 2, and in series with resistor R, is connected an impedance denoted as Z. There is applied between the signal grid and the grounded end of resistor R alternating current voltage e . The plate 5 is connected to the positive terminal of source 3, while screen electrode 6 is connected to a point of less positive potential. Let E_{gc} be the potential difference between grid and cathode; g is the transconductance of tube 1; i_c is the current flowing from the cathode through R; i is the current flowing through Z. Then, the following relations exist in Fig. 1:

$$i_c = E_{gc}g$$

$$e = iZ + R(i_c + i)$$

$$E_{gc} = iZ$$

therefore,

$$e = iZ + Ri + R(g)iZ$$

therefore,

$$e/i = Z(1 + gR) + R$$

If the product of Z and g is much greater than unity then, approximately, the effective impedance between the input terminals is $Z(1 + gR)$. That is, the effective impedance is multiplied.

It is desirable to have Z much greater than R . If, now, Z is a tuned circuit, multiplying its impedance broadens its response, when connected across a finite impedance circuit. That is, the inductance and capacitive branches of the tuned circuit are each increased in reactance by the same degree. Thus their LC product remains constant, but the L/C ratio increases. This ratio, as known to the art, is a factor determining broadness of a tuned circuit in shunt to a finite impedance circuit. In a similar manner, if Z is an untuned reactance, such as the coupling capacity of a band pass filter, a similar result is secured. There will now be disclosed two circuits utilizing these respective actions of the invention.

In Fig. 2, let it be assumed that the tuned signal circuit comprises coil 7 shunted by condenser 8. Signals may be applied to the signal circuit from any desired source. The high potential input terminal may be connected to the high potential side of the tuned circuit 7—8 through a direct current blocking condenser 9. The low potential input terminal is established at ground potential. The control tube 1, as shown at Fig. 1, has its signal grid 4 connected to the high potential end of 7—8, while the cathode 2 is connected to the low potential side of the tuned circuit. The unby-passed resistor R connects cathode 2 to ground. Hence, the circuit 7—8 acts as the impedance Z of Fig. 1 in series with the degenerative resistor R . The direct current voltage developed across resistor R is applied as a negative bias to grid 4 through leak resistor 10. Condensers 11 and 12 are direct current blocking condensers. The signal voltage across 7—8 is transmitted through condenser 12 to a subsequent stage. The screen 6 and plate 5 of tube 1 have appropriate positive voltages applied thereto from the supply source bleeder 13. The tap 14 is connected to the screen through a reducing resistor.

There is shown in Fig. 3 the effect of control tube 1 on the response characteristic of the tuned circuit 7—8. In Fig. 3 "Frequency" is plotted as abscissae against "Attenuation" as ordinates. It will be seen from this figure that when the tap 14 is adjusted to decrease the positive potentials on electrodes 6 and 5 the tube G_m is high in value. The curve in Fig. 3 designated as "High G_m " shows the resulting response characteristic. There occurs an increased attenuation of the higher side band components of the modulated carrier energy. In other words, this curve shows the adjustment for high selectivity, or sharp response, for tuned circuit 7—8. On the other hand when the tap 14 is adjusted in the opposite direction so that tube 1 has a low value of G_m , the attenuation of the side band components is greatly decreased. This corresponds to a broad response of the tuned circuit.

Of course, the source of signals may be the usual signal collector device of a radio broadcast receiver, or it may be the output terminals of the first detector of a superheterodyne receiver. In the former case the condenser 8 would be adjustable so as to adjust the tuned circuit to different carrier frequencies of any desired carrier frequency range. For instance, if the frequency range were the 550–1700 kilocycles broadcast band, then circuit 7—8 would be tuned through this band to different audio-modulated carrier frequencies. On the other hand, if the circuit 7—8 is in the intermediate frequency

amplifier of a superheterodyne receiver, then the circuit would be fixedly tuned to the operating intermediate frequency, such as 455 kilocycles. It is, also, to be understood that this invention may be applied to a frequency modulated carrier wave receiver. In such case the circuit 7—8 can be either in the tunable selector stage, or in the intermediate frequency amplifier stage. In either case the circuit 7—8 would be tuned to the center frequency of the band. In brief, then, there is disclosed in Fig. 2 between input and output terminals a tuned signal circuit which is arranged between the input electrodes of an electron discharge tube including a degenerating resistor in its cathode circuit. Adjustment of the gain of the tube results in a variation of the response characteristic of the tuned circuit.

In Fig. 4 there is shown the manner of utilizing the control tube to vary the magnitude of the untuned coupling reactance of a band pass filter network. Assuming, for example, that the input signals are applied to resonant branch 20—21 of the filter network, then the output terminals would be connected to the second resonant branch 22—23. Each of the branches is tuned to the carrier, or center, frequency of the band transmitted through the filter network. The condenser 24 functions as the untuned coupling reactance common to both branches of the network. The magnitude of condenser 24 is chosen so as to provide a band pass response characteristic for the circuit as in conventional band pass filters, and this circuit differs only in that the value of condenser 24 is determined by the transconductance of tube 30. From filter theory it is known that decreasing the effective capacity of condenser 24 moves the upper cut-off frequency up while the lower cut-off frequency remains stationary thereby accounting for a broader pass range. One terminal of the reactance 24 is connected to the low potential side of the network, while the opposite terminal is connected through the degenerating resistor 39 to the junction of condensers 21 and 22. The control tube is designated by 30, and it has its cathode connected to the —B terminal of the power supply source through the resistor 39. The plate of the control tube is connected to a desired point on the voltage supply bleeder 31 through an adjustable tap 32, the tap 32 being by-passed for signal frequencies by the condenser 33. The control grid of the tube 30 is connected to the low potential point of the filter network in common with one end of condenser 24.

In Fig. 5 there is shown graphically a pair of curves similar to those shown in Fig. 3. Here, again, the curve denoted "High G_m " results in a narrow band pass characteristic when tap 32 is adjusted so that tube 30 has its maximum G_m value. On the other hand, the second curve results in a wide band pass characteristic when tube 30 is adjusted to have a low value of G_m . It will, therefore, be seen that in Fig. 4 there has been disclosed an electronic device for varying the magnitude of an untuned reactance which is arranged between the input electrodes of a tube including a degenerating resistor in its cathode circuit.

While in the arrangements of Figs. 2 and 4 the degenerative electronic device is employed to vary the response characteristic of a tuned network, in Fig. 6 there is shown a method of utilizing the device to vary the tuning of a signal cir-

cuit over a wide frequency range. In this modification, a capacitor or inductor, acting as the variable tuning element, is placed between the control grid and cathode of a tube whose cathode circuit includes the degenerating resistor. Adjustment of the tube transconductance results in a variation of the magnitude of the capacitor or inductor. Where several tuned circuits must be ganged, a single source of adjustable direct current voltage may be used to vary the tuning of all the tuned circuits simultaneously. An advantage of this type of system resides in the possibility of remote tuning, since the tuning potentiometer has no radio frequency voltage directly associated with it.

Considering, now, the circuit details of Fig. 6, let it be assumed that the collected modulated carrier waves, whether amplitude or frequency modulated, are applied to transformer 40 whose secondary coil 41 acts as the input coil of the first detector signal input circuit. The signal circuit tuning condenser is denoted by numeral 42, and the latter is connected in shunt with coil 41 through a path including unby-passed resistor 43 and lead 44. The first detector tube 45 has its signal grid connected to the high end of coil 41, while the cathode is connected to ground through the self-biasing resistor 46. The oscillation input electrode 47 is surrounded by a positive screening field, and the output electrode 48 is connected to the tuned primary circuit of the intermediate frequency transformer 49. Each of the primary and secondary circuits of the latter is tuned to the operating intermediate frequency, which may be 455 kilocycles.

The intermediate frequency energy is amplified in one or more stages of amplification, and the amplified signal energy is then demodulated. The demodulated signals are amplified, and finally reproduced. The local oscillations for the first detector are provided by tube 50 whose plate 51 is connected to one end of coil 52. An intermediate point on the coil is connected to a source of positive energizing voltage, the point being coupled additionally by the direct current blocking condenser 53 to the grounded cathode. The control grid of the oscillator tube 50 is connected to the end of coil 52 opposite from the plate connection by the padding condenser 54. The shunt trimmer condenser 55 across coil 52 cooperates with the series condenser 54 to maintain the oscillation frequency constantly differing from the signal frequency at any setting of the tuning means. Grid leak resistor 56 connects the grid to the cathode.

The tuning condenser for coil 52 is designated by numeral 60. The latter has one end connected to the grid of the oscillator, while the opposite end is connected to ground through resistor 70 acting as the degenerating resistor for the control tube 71. Tube 72 acts as the tuner tube for coil 41, and between its signal grid and cathode is connected the condenser 42. Similarly, tube 71 has condenser 60 connected between its grid and cathode, and tube 71 functions as the tuning control for coil 52. Each of the capacitors 42 and 60, therefore, decrease in effective magnitude with increased transconductance of their respective tubes 72 and 71. This decrease may in extreme cases amount to as much as 85 to 90 percent. Both plates of tubes 71 and 72 are connected to a source of positive voltage, and by-passed to ground through a condenser. The screen grids of tubes 71 and 72 are connected to the voltage

source through the voltage reducing resistor, and are by-passed to ground through condenser 74.

Each of the grids 80 and 90 of tubes 71 and 72 respectively are by-passed to ground through condenser 75, and are connected by adjustable tap 100 to a voltage reducing resistor 101 connected between the screen voltage supply lead and the ground lead 44. Variation of the tap 100 along resistor 101 results in adjustment of the gain of each of tubes 71 and 72. Each of resistors 43 and 70 provides the normal bias for the input grids of tubes 72 and 71 respectively. Adjustment of the voltage of grids 90 and 80 over a wide voltage range results in a variation of the capacity value of each of condensers 42 and 60. The local oscillations produced by the local oscillator are applied to the grid 47 by lead 47' connected to plate 51. The gain of tube 71 will be adjustable over a range of values such that the capacity of 60 will be capable of varying the frequency of the tank coil 52 over the desired frequency range. Simultaneously the gain of tube 72 will be varied so as to have condenser 42 adjust coil 41 over the desired signal range. The dotted line sections in the leads to tap 100 and resistor 101 denote the fact that these elements may be located at a remote point relative to the receiver proper. Furthermore, each of the signal circuits prior to coil 41 may be provided with its own tuning control tube.

Of course, the receiver could be of the tuned radio frequency amplifier type. Also, in such situations where only an oscillator is employed, the invention can readily be applied thereto.

While I have indicated and described several systems for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organizations shown and described, but that many modifications may be made without departing from the scope of my invention, as set forth in the appended claims.

What I claim is:

1. In combination with signal input terminals and output terminals, a reactive impedance coupling said input and output terminals, an electron discharge tube provided with input and output electrodes, said tube including an unby-passed resistive impedance arranged in the space current path thereof and common to its input and output electrodes, means connecting said reactive impedance between the input electrodes of said tube, said reactive impedance and said resistive impedance being arranged in series relation across the signal input terminals, said signal output terminals being connected across solely said series impedances, and means for varying the transconductance of said tube thereby to vary the effective magnitude of said reactive impedance.

2. In combination with signal input terminals and output terminals, a reactive impedance coupling said input and output terminals, an electron discharge tube provided with input and output electrodes, said tube including an unby-passed resistive impedance arranged in the space current path thereof and common to its input and output electrodes, means connecting said reactive impedance between the input electrodes of said tube, said reactive impedance and said resistive impedance being arranged in series relation across the signal input terminals, and means for varying the transconductance of said tube thereby to vary the effective magnitude of said reactive impedance, said reactive imped-

ance consisting of at least one resonant circuit tuned to a desired signal carrier frequency.

3. In combination with signal input terminals and output terminals, a reactive impedance coupling said input and output terminals, an electron discharge tube provided with input and output electrodes, said tube including an unby-passed resistive impedance arranged in the space current path thereof and common to its input and output electrodes, means connecting said reactive impedance between the input electrodes of said tube, said reactive impedance and said resistive impedance being arranged in series relation across the signal input terminals, and means for varying the transconductance of said tube thereby to vary the effective magnitude of said reactive impedance, said reactive impedance being untuned.

4. An electronic reactive impedance device comprising an electron discharge tube including at least a cathode, a control electrode and an anode electrode, an unby-passed resistive impedance arranged in the space current path of said tube, said resistive impedance being common to the control electrode and anode circuits of said tube, a reactive impedance arranged in series with said resistive impedance and being connected between said control electrode and cathode, means for impressing alternating current voltage upon said control electrode, and means for varying the gain of said tube thereby to vary the effective magnitude of said reactive impedance, said reactive impedance consisting of a resonant circuit tuned to a desired signal frequency, said alternating current voltage being of signal frequency and means for connecting a signal output circuit across solely said series impedances.

5. In combination with a pair of reactances of opposed polarity sign connected to provide a tuned circuit, an electron discharge tube provided with at least a cathode, control grid and plate, both of said reactances being connected between solely said grid and cathode, an unby-passed resistor in the cathode circuit of the tube common to said grid and plate, said tuned circuit and resistor being connected in series relation, means for connecting a signal output circuit across the series-connected circuit and resistor, and means for adjusting the transconductance of said tube over a wide range of values thereby to vary the effective response of said tuned circuit over a wide range of values.

6. In combination with a pair of reactances of opposed polarity sign connected to provide a tuned circuit, an electron discharge tube provided with at least a cathode, control grid and plate, both of said reactances being connected between solely said grid and cathode, an unby-passed resistor in the cathode circuit of the tube common to said grid and plate, said tuned circuit and resistor being connected in series relation, means for connecting a signal output circuit across the series-connected circuit and resistor, and means, including an auxiliary electrode within said tube, for adjusting the transconductance of said tube thereby to vary the effective response of said tuned circuit over a wide range of values.

7. In combination with a pair of reactances of opposed polarity sign connected to provide a

tuned circuit, an electron discharge tube provided with at least a cathode, control grid and plate, both of said reactances being connected between solely said grid and cathode, an unby-passed resistor in the cathode circuit of the tube common to said grid and plate, said tuned circuit and resistor being connected in series relation, means for connecting a signal output circuit across the series-connected circuit and resistor, and means for adjusting the transconductance of said tube over a wide range of values thereby to vary the effective selectivity of said tuned circuit over a wide range of values, said one reactance being a condenser, and the second reactance being a coil in shunt with the condenser.

8. In combination, an electron discharge tube including at least a cathode, a control electrode and an anode electrode, an unby-passed resistive impedance arranged in the space current path of said tube, said resistive impedance being common to the control electrode and anode circuits of said tube, a signal-tuned circuit arranged in series with said resistive impedance and being connected between said control electrode and cathode, a signal-tuned output circuit connected across solely said series-arrangement, and means for varying the mutual conductance of said tube thereby to vary the effective magnitude of the impedance of said tuned circuit whereby the broadness of its response is varied.

9. In combination with a pair of cascaded resonant networks connected to provide a tuned band pass circuit, an electron discharge tube provided with at least a cathode, control grid and plate, an untuned reactance being connected between said grid and cathode, an unby-passed resistor in the cathode circuit of the tube common to said grid and plate, said reactance and resistor being connected in series relation, said networks being directly coupled to each other by solely said series-connected reactance and resistor, and means for adjusting the transconductance of said tube over a wide range thereby to vary the effective magnitude of said reactance over a wide range of values whereby the pass range of the band pass circuit is adjusted.

10. In combination with the first detector and local oscillator tubes of a radio receiver, a tunable signal circuit connected to the first detector input electrodes, a tunable tank circuit operatively associated with the oscillator tube electrodes, each of said signal and tank circuits having its respective tuning reactance; an improvement comprising a first electron discharge tube having at least a grid, cathode and anode, an unby-passed resistor connected in the cathode circuit of said first tube, the tuning reactance of the signal circuit being connected in series with the resistor and between said grid and cathode, a second tube, constructed in the same manner as the first tube, including the tank circuit tuning reactance between its grid and cathode, and means remote from said receiver for adjusting the gain of each of said first and second tubes thereby to vary the tuning of said signal and tank circuits.

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