

March 2, 1943.

B. TREVOR

2,312,783

FREQUENCY VARIATION RESPONSE CIRCUIT

Filed Oct. 25, 1941

2 Sheets-Sheet 1

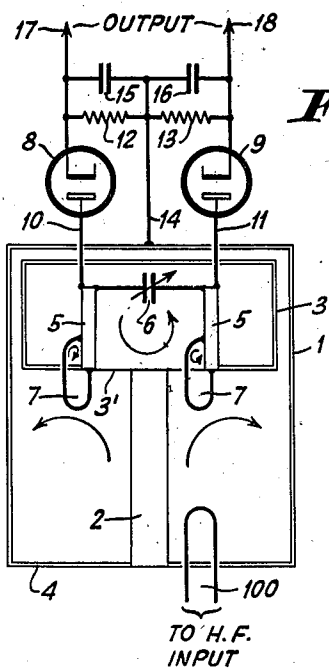


Fig. 1

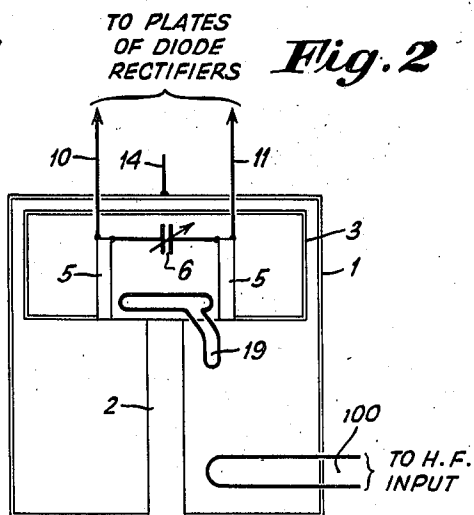


Fig. 2

Fig. 3

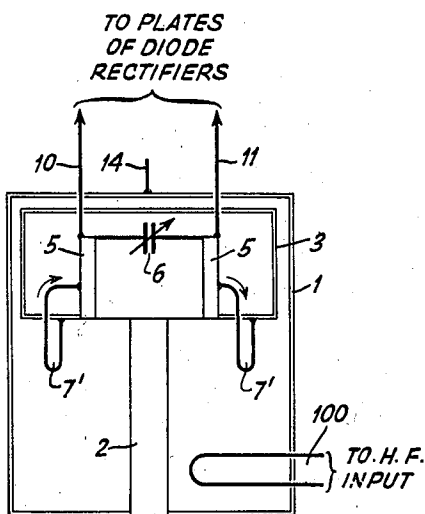
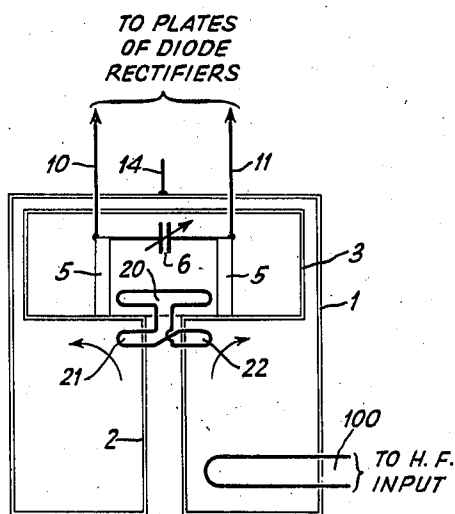


Fig. 4



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*Fig. 6*

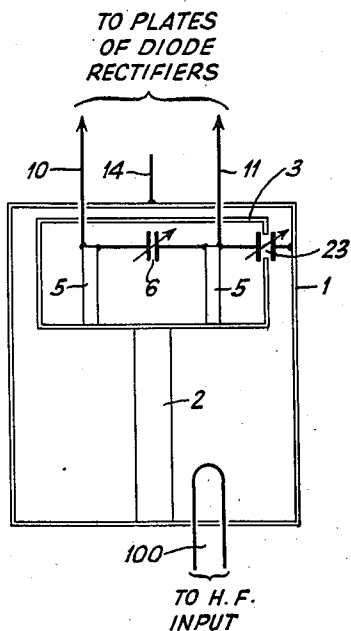


*Fig. 5*

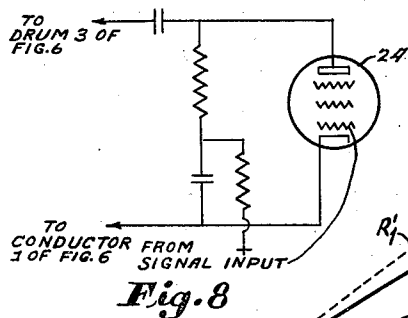
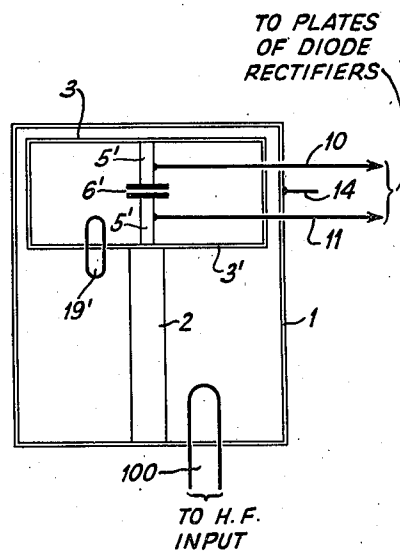
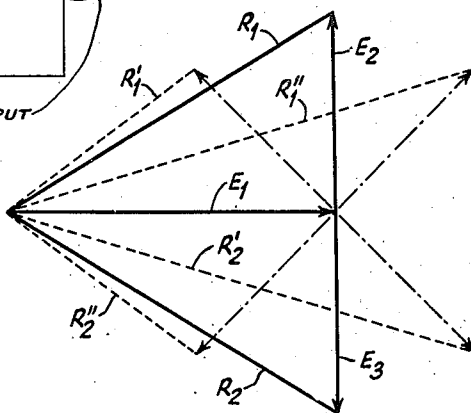


*Fig. 7*



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## UNITED STATES PATENT OFFICE

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FREQUENCY VARIATION RESPONSE  
CIRCUIT

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Application October 25, 1941, Serial No. 416,458

9 Claims. (Cl. 250-40)

This invention relates to high frequency variation response circuits, and more particularly to frequency response networks of a type utilizing changes in phase relations of primary and secondary circuit voltages which occur in coupled tuned circuits when the applied high frequency energy departs from the resonance frequency of the tuned circuits. Circuits of this general type are commonly referred to as frequency discriminator circuits.

An object of the present invention is to provide a discriminator network whose tuned circuits are composed of transmission line sections.

Another object is to provide a discriminator circuit which can be used as a monitor without the necessity for reducing the received ultra high frequency energy to energy of a lower frequency, as is required in known types of discriminator circuits employing coils in the tuned circuits.

A still further object is to provide a discriminator circuit of great mechanical stability which avoids microphonic trouble, such as might be due to mechanical vibration.

A still further object is to provide a compact and rugged low-loss discriminator circuit which is advantageous for use with a narrow percentage band width of received signal.

The discriminator circuit of the present invention finds particular application wherever there is need for a frequency response network which supplies a direct current output whose magnitude varies in dependence upon the variation of frequency of the applied energy from the resonance frequency of the tuned circuits of the network. More specifically, the high frequency variation response circuit of the invention can be used in an automatic frequency control system, or in a receiving system employed to receive frequency modulated carrier waves. If used to receive frequency modulated carrier waves, the frequency variation response network is utilized in connection with the detection of frequency modulated waves, as known in the art.

A more detailed description of the invention follows in conjunction with drawings, wherein Figs. 1 to 6 and 8 illustrate six different embodiments of the present invention, and Fig. 7 illustrates graphically, by means of vector diagrams, the operation of the high frequency variation response circuit of the invention.

In the drawings, the same parts are represented by the same reference numerals throughout the figures.

Referring to Fig. 1 in more detail, there is shown coupled to the input circuit 100 a high frequency concentric line resonator comprising an outer conductor 1 and an inner conductor composed of two sections of different diameters; namely, a small diameter section 2 and a large

diameter section 3. The inner and outer conductors are conductively coupled together at the bottom by means of a metallic end plate 4 and capacitively coupled at their other ends mainly by virtue of the larger diameter section 3, which may be referred to as a hollow capacity drum. In the operation of the concentric line resonator 1, 2, 3, the smaller diameter section 2 of the inner conductor forms with the outer conductor 1 an effective inductance, while the larger diameter section 3 of the inner conductor forms with the outer conductor 1 an effective capacitance. It should be noted that the capacity drum 3 is, in effect, mounted at the high potential end of the smaller diameter section 2. Within the interior of the hollow capacity drum 3, there is provided another tuned circuit composed of a pair of parallel metallic rods 5, 5 which are conductively coupled together at one end by the wall 3' of the capacity drum and capacitively coupled together at their other ends by means of a variable condenser 6. In effect, it may be said that the rods 5, 5 compose a lecher wire system which is loaded at one end by the variable capacity 6 in order to shorten considerably the length of the tuned circuit. The two tuned circuits 1, 2, 3 and 5, 5, 6 are both tuned to the same frequency and are inductively coupled together by means of wire loops 7, 7 which extend from the interior of the capacity drum 3 through apertures in the wall 3' to the interior of the resonator 1, 2, 3 in such manner that the tuned circuit within the hollow capacity drum is excited by the electromagnetic field in the resonator 1, 2, 3. At the same time, the electrical center of tuned circuit 5, 5, 6 is directly connected to the high potential end of tuned circuit 1, 2, 3. Because the tuned circuit 5, 5, 6 is excited from the tuned circuit 1, 2, 3, the latter in turn being coupled to the source of high frequency waves 100, the last tuned circuit can be considered to the primary circuit while the former tuned circuit can be considered to be the secondary circuit. The directions of the arrows are merely given to illustrate the directions of the currents in the various elements of the two tuned circuits and in the coupling loops. Although two coupling loops 7, 7 have been shown to provide a balance in the coupling arrangement between the two tuned circuits, it should be understood that the tuned circuit 5, 5, 6 can be excited from the tuned circuit 1, 2, 3 merely by means of a single loop. From what has been said above, it will be evident that the tuned circuit 5, 5, 6 within the capacity drum 3 is mounted at the high potential point of the inner conductor of the outer resonator.

A pair of diodes 8, 9 have their anodes connected by means of leads 10 and 11, respectively, to the ends of the rods 5, 5 which are

remote from the end plate 3'. The cathodes of the diodes 8, 9 are connected together by means of resistors 12 and 13, the junction point or midpoint of which is connected by means of a lead 14 to the outer conductor 1 of the resonator 1, 2, 3. This outer conductor can be considered as a neutral or ground point for current of radio frequency energy. The resistors 12 and 13 are shunted by by-pass condensers 15 and 16, whose junction point is connected to the electrical center or neutral point of the resistors 12 and 13. The outputs of the diodes or rectifiers 8, 9 in the form of direct current voltages are derived from the terminals 17 and 18.

The operation of Fig. 1 may be better understood by reference to Fig. 7, which shows vectorially the relative phases of the voltages in the two tuned circuits of the discriminator circuit of the invention. The line  $E_1$  represents the voltage vector of the tuned circuit 1, 2, 3, and the arrow of this line indicates the high potential end of this voltage vector. The vectors  $E_2$  and  $E_3$  on a line at right angles to the voltage vector  $E_1$  represent, respectively, the voltages applied to the plates or anodes of the detectors 8 and 9 through leads 10 and 11. These vectors are equal and opposite in sense to each other. The resultants  $R_1$  and  $R_2$  are the direct current voltages across the diode load resistors 12 and 13 for a steady state carrier condition at the resonance frequency of the two tuned circuits composed of two transmission line sections 1, 2, 3 and 5, 5, 6. These direct current voltages are variable across the terminals 17 and 18. So long as the high frequency carrier supply to the input circuit 1 has the same frequency as the resonance frequency of the two tuned transmission line circuits, the vectors  $E_2$  and  $E_3$  will be at right angles to the vector  $E_1$ , and the resultants  $R_1$  and  $R_2$  will be equal to each other in magnitude. Thus there will be no voltage difference between terminals 17 and 18. The frequency of the carrier corresponding to the resonance frequency of the two tuned circuits can be considered the midband frequency of the applied input wave. However, if the carrier or midband frequency of the input circuit deviates in one direction, the phases of the vectors  $E_2$  and  $E_3$  will depart from the 90° relation and may take a position indicated by the dash lines to form with vector  $E_1$  the new resultants  $R'_1$  and  $R'_2$ . These new resultants indicate that one diode rectifier receives more voltage and the other receives less voltage. If the carrier or midband frequency deviates in an opposite direction, the vectors  $E_2$  and  $E_3$  again depart from their 90° phase relation relative to the vector  $E_1$  and may assume the position indicated by the dot and dash line to form resultants  $R''_1$  and  $R''_2$ , whereby the diode rectifiers now receive different voltages in an opposite sense. It will thus be seen that the anodes of the diode rectifiers are excited by the radio frequency voltages of the combined tuned circuits 5, 5, 6 and 1, 2, 3 and function to provide different direct current voltages across the diode resistors which are dependent upon the degree of departure of the applied high frequency energy from the midband or resonance frequency of the two tuned circuits. Obviously, the vector diagram of Fig. 7 indicates only three selected conditions of steady state carrier waves. In practice, the carrier continuously changes in frequency and the resultant direct current voltages across the load

resistors continuously vary between two limits representative of the two extreme frequency departures of the carrier wave from the mid-band frequency.

Another way of looking at the discriminator circuit of the invention is to consider the outer transmission line resonator 1, 2, 3 as a single ended tuned circuit, and to consider the enclosed transmission line tuned circuit 5, 5, 6 (tuned to the same frequency as the first tuned circuit) as a push-pull circuit. The coupling loops 7, 7 indicate means by which energy is transferred from the single ended circuit to the push-pull circuit.

The discriminator circuit of the invention, it should be noted, is a mechanical and rugged affair which can be made to have a minimum of vibration, and because the transmission line sections are particularly adapted to function at ultra high frequencies with minimum losses, the tuned circuits can be made to have a very high Q for narrow percentage band width operation. I am thus able to provide a discriminator circuit which can function at the ultra high frequencies applied directly to the receiver, without the need for reducing the received waves to an intermediate frequency wave before the voltage is applied to the discriminator circuit.

Figs. 2, 3 and 4 are substantially identical with Fig. 1, except for the manner of transferring the energy from the outer tuned circuit to the inner tuned circuit. The diode rectifier circuits have not been shown in Figs. 2, 3 and 4, or in Figs. 5 and 6, because they take substantially the same form shown in Fig. 1 and have been omitted in order to simplify the drawings. The leads 10, 11 and 14 extending from the resonator circuits to the diode rectifier circuit have been indicated in Figs. 2 to 6, and these correspond to the leads of the same reference numerals in Fig. 1. It should be noted in Fig. 2 that a single loop 19 is shown having one end in the cavity space of the outer resonator and the other end located in the capacity drum between the rods 5, 5. In Fig. 3 the loops 7', 7' are arranged differently with respect to the arrangement of the coupling loops of Fig. 1. In Fig. 4 there is shown a coupling circuit comprising a single loop 20 located between the rods 5, 5 which is connected to a pair of loops 21, 22 in the space between the conductors 2 and 1 of the outer resonator. All three loops 20, 21 and 22 are so connected that the currents therein flow in the same direction.

Fig. 5 illustrates a variation of the inner tuned circuit 5, 5, 6 of Figs. 1 to 4. In Fig. 5 the tuned circuit within the capacity drum 3 comprises a push-pull type of concentric line resonator whose outer conductor consists of the inner surface of the drum 3 and whose inner conductor consists of a pair of coaxial rods 5', 5' placed end to end on the same straight line and separated from one another at their adjacent ends by means of a pair of capacity plates to form a capacitor 6'. The tuned circuit 5', 5', 6', 3 is tuned to the same frequency as the outer resonator 1, 2, 3. Tuning of the inner tuned circuit 5', 5', 6', 3 can be achieved by varying the spacing between the capacitor plates of the condenser 6'. Coupling between the two tuned circuits of Fig. 5 is achieved by means of a single turn coil 19', which extends through an aperture in the wall 3' of the drum 3, so that one-half of the coil is located in the field of the outer resonator while the other half is located in

the field of the inner resonator in order to couple with one of the rods 5'.

Fig. 6 shows an arrangement substantially identical with Figs. 1 to 4, except for the manner of coupling the two tuned circuits 1, 2, 3 and 5, 5, 6 together. Whereas the tuned circuits of Figs. 1 to 4 are shown coupled inductively, the tuned circuits of Fig. 6 are shown capacitively coupled together by means of a variable capacitor 23. This variable capacitor comprises a pair of adjustable plates on opposite sides of one side wall of the capacity drum 3, there being an aperture in this side wall registering with the center portions of the plates of the condenser 23. It will thus be evident that in Fig. 6 the high potential end of the tuned circuits 1, 2, 3 is capacitively coupled to one of the high potential terminals of the tuned circuit 5, 5, 6 by means of a capacitor 23. Fig. 8 shows an alternative method of feeding input energy to the outer transmission line resonator 1, 2, 3 by way of an electron discharge device pentode 24 whose cathode is connected to ground (ground being represented by the outer conductor 1) and whose plate or anode is connected by way of a blocking condenser to the capacity drum 23. The first grid of the pentode 24 represents the signal grid. This pentode may comprise the limiter tube of a frequency modulated receiver. The pentode construction shown is obviously an alternative for the high frequency input circuit 100. It should be apparent that this same pentode construction can be employed as the input circuit in any of the discriminator circuits shown in Figs. 1 to 5, in place of the high frequency input circuit 100.

What is claimed is:

1. In a frequency variation response network, a first resonant circuit in the form of a section of coaxial transmission line, the inner conductor of which is hollow at its high alternating potential end, a second resonant circuit also in the form of a section of transmission line and tuned to the same frequency as said first circuit, said second circuit being located within and directly connected at its electrical center to the hollow portion of said inner conductor, means for reactively exciting said second resonant circuit from said first resonant circuit, means for deriving potentials of opposite polarities from symmetrical points on the second resonant circuit and rectifying the same, and means for adding the resultant direct current voltages in opposition.

2. In a frequency variation response network, a resonant line having inner and outer conductors, said inner conductor having two sections of different diameter, the smaller diameter section of the inner conductor contributing the main inductive component while the larger diameter section of the inner conductor contributes the main capacitive component of said resonant line, another resonant circuit composed of a section of transmission line enclosed within said larger diameter section, said enclosed resonant circuit being tuned to the same frequency as said first resonant line and having one point directly connected to said larger diameter section, a capacitor forming part of said enclosed resonant circuit, means for exciting said second resonant circuit from said first resonant circuit, a pair of rectifiers having corresponding electrodes coupled to opposite sides of said capacitor, and a pair of load resistors connected to other corresponding electrodes of said rectifiers, whereby

resultant direct current voltages across said resistors can be added in opposition.

3. A network in accordance with claim 2, characterized in this that said means for exciting the second resonant circuit from the first resonant circuit includes a loop extending from the space between the conductors of said first resonant circuit to the space between the conductors of said second resonant circuit.

4. A network in accordance with claim 2, characterized in this that said means for exciting the second resonant circuit from the first resonant circuit includes a loop extending from the space between the conductors of said first resonant circuit to a point on one of the conductors of said second resonant circuit.

5. A network in accordance with claim 2, characterized in this that said means for exciting the second resonant circuit from said first resonant circuit includes a capacitor, one plate of which is connected to the outer conductor of said first circuit and the other plate of which is connected to one conductor of said second resonant circuit by a connection which passes through an aperture of said larger diameter section, said plates being coupled to each other and to said larger diameter section at the location of said aperture.

6. In a frequency variation response network, two transmission line circuits tuned to the same frequency, one being a single ended circuit and the other a push-pull circuit, said push-pull circuit being mounted on the high potential end of said single ended circuit, means reactively coupling said two tuned circuits together, a pair of detectors, connections from said detectors to symmetrical points on said push-pull circuit to energize said detectors with alternating current energy, and means for utilizing the difference between the outputs of said detectors.

7. A network in accordance with claim 2, characterized in this that said enclosed resonant circuit is composed of a pair of coextensive spaced parallel rods of the same dimensions.

8. A network in accordance with claim 2, characterized in this that said enclosed resonant circuit is composed of a concentric line resonator having an inner conductor comprising two rods placed end to end and capacitively coupled at their adjacent ends.

9. In a frequency variation response network, a resonant line having inner and outer conductors, said inner conductor having two sections of different diameter, the smaller diameter section of the inner conductor contributing the main inductive component while the larger diameter section of the inner conductor contributes the main capacitive component of said resonant line, another resonant circuit composed of a section of transmission line enclosed within said larger diameter section, said enclosed resonant circuit being tuned to the same frequency as said first resonant line and having one end directly connected to said larger diameter section, a capacitor across the other end of said enclosed resonant circuit, means for exciting said second resonant circuit from said first resonant circuit, a pair of rectifiers having corresponding electrodes coupled to opposite sides of said capacitor, and a pair of load resistors connected to other corresponding electrodes of said rectifiers, whereby resultant direct current voltages across said resistors can be added in opposition.

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