June 17, 1947. R. S. YEANDLE 2,422,513

FREQUENCY RESPONSIVE NETWORK

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Fig. 1.

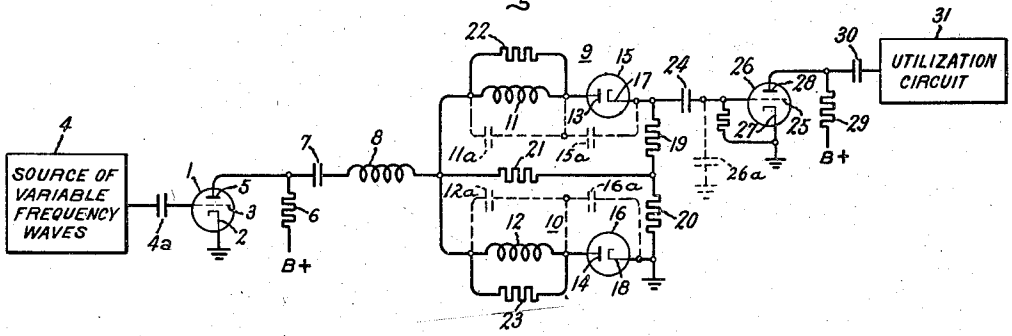
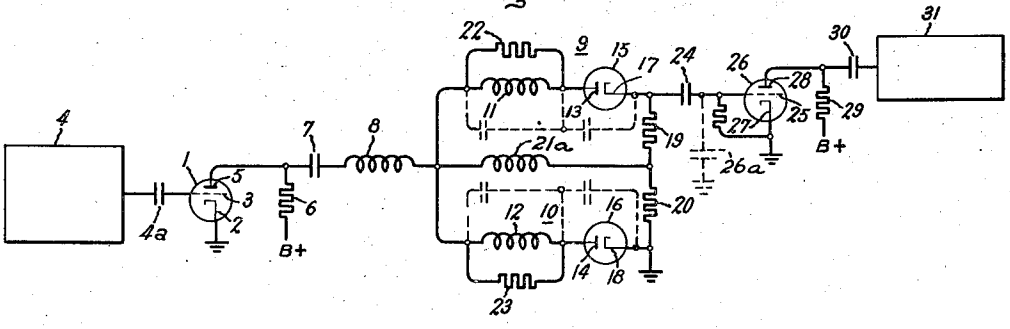


Fig. 2.



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FREQUENCY RESPONSIVE NETWORK

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My invention relates to frequency responsive networks, and more particularly to wide band frequency discriminating circuits. The invention is useful for automatic frequency control and for demodulation of frequency modulated signals, especially when the magnitude of the frequency excursions to either side of the mean frequency is a large percentage of the mean frequency. The invention, therefore, is particularly well adapted for the demodulation of frequency modulated video signals in television apparatus.

It is a general object of my invention to provide a new and improved wide band frequency responsive network.

It is a further object of my invention to provide a new and improved wide band frequency discriminating circuit which exhibits a high degree of linearity of frequency response.

It is a more specific object of my invention to provide means for increasing the band width and improving the linearity of frequency response in a frequency responsive network comprising a pair of oppositely mistuned series resonant circuits connected in parallel.

My invention itself will be more fully understood and its objects and advantages further appreciated by referring now to the following detailed specification taken in conjunction with the accompanying drawing, in which Fig. 1 is a schematic circuit diagram of a frequency responsive network embodying my invention in one form, and Fig. 2 is a schematic circuit diagram of a frequency responsive network embodying my invention in another form.

Referring now to the drawing, and particularly to Fig. 1, I have shown an amplifier 1 having a cathode 2 connected to ground and a control electrode 3 supplied with electric oscillations of variable frequency from a source 4 through a coupling condenser 4*a*. It will be understood, of course, that the source of oscillations 4 may provide oscillations modulated in frequency about a predetermined mean frequency in accordance with a desired signal or may supply oscillations subject to occasional undesired variations from a desired fixed frequency.

The anode 5 of the amplifier 1 is connected to a non-resonant output circuit including a load resistor 6, and the amplified output voltage is supplied through a coupling capacitor 7 to a frequency discriminating circuit including an inductive impedance 8 and a pair of opposed rectifying circuits 9 and 10. The rectifying circuits 9 and 10 include separate inductive impedances 11 and 12, respectively, connected together at one terminal and having their other terminals connected respectively to the anodes 13 and 14 of a pair of rectifying diodes 15 and 16, respectively. The cathodes 17 and 18 of the diodes 15 and 16, respectively, are connected to the electrically remote terminals of a pair of load resistors 19 and 20 having their opposite terminals connected together. The rectifying circuits 9 and 10 have a common return path from the common terminal of the load resistors 19 and 20 through a resistor 21 to the common terminal of the impedances 11 and 12. The inductances 11 and 12 are shunted by loading resistors 22 and 23, respectively. The inductance 8 is connected between the coupling condenser 7 and the common terminal of inductances 11 and 12.

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The cathode 18 of the diode 16 is connected to ground, and the cathode 17 of the diode 15 is connected through a coupling condenser 24 to the control electrode 25 of a signal amplifying discharge device 26. The discharge device 26 includes also a grounded cathode 27 and an anode 28 connected to an output circuit including a load resistor 29. The voltage across the load resistor 29 is supplied through a coupling condenser 30 to a suitable utilization device 31.

In operation, it is believed that the stray circuit capacitance shunted across the remote terminals of the separate inductive elements 11 and 12 is sufficient to form with these elements a parallel resonant circuit tuned approximately to a predetermined mean frequency within the band of frequencies supplied from the source 4. Such stray circuit capacitance has been illustrated by capacitors 11*a* and 12*a* in dotted lines shunted across the inductors 11 and 12, respectively. It will, of course, be understood that, if necessary and desirable, additional capacitance may be connected between the anodes 13 and 14 of the diodes 15 and 16 to effect the proper parallel tuning.

The circuit of Fig. 1 includes also a pair of oppositely mistuned series resonant circuits connected in parallel circuit relation between the output terminal of the coupling condenser 7 and ground. One of these circuits includes the common inductance 8, the inductance 11, and the interelectrode capacitance of the discharge devices 15 and 26. Such interelectrode capacitance has been illustrated by capacitors 15*a* and 26*a* in dotted lines shunted across the devices 15 and 26, respectively. The other series resonant circuit includes the common inductance 8, the inductance 12, and the interelectrode capacitance of the diode discharge device 16. The interelectrode capacitance of the diode 16 is illustrated by a

capacitor 16*a* in dotted lines shunted across the device 16. The values of inductance and capacitance in these two series resonant circuits are so proportioned that the circuits are tuned to frequencies slightly displaced to either side of the predetermined mean frequency. Such tuning is controlled by proportioning of the inductances 11 and 12 and also by proportioning of the capacitance between the electrically remote terminals of these inductances and ground. It will of course be understood by those skilled in the art that, if desired, the interelectrode capacitance of the discharge devices in these series resonant circuits may be supplemented by additional capacitance connected between the anodes 13 and 14 and ground. The resistors 22 and 23 are included to load the series resonant circuits to such an extent that current of approximately the same intensity flows in each series circuit at its resonant frequency. It will of course be understood by those skilled in the art that either one or both of the resistors 22, 23 may, in a particular case, be found unnecessary.

It will now be evident from the foregoing description that, when oscillations of a predetermined mean frequency midway between the resonant frequencies of the two series resonant circuits are supplied to the discriminating circuit, the voltages appearing across the inductances 11 and 12 will be approximately equal, so that the rectified voltages across the load resistors 19 and 20 will be approximately equal. Since the rectifier circuits 9 and 10 are connected in opposing relation, equal unidirectional potentials appear at the remote terminals of the resistors 19 and 20 when the voltage drops across the resistors are equal. If now the frequency of the oscillations supplied from the source 4 varies in one direction or the other from the mean frequency, the voltage drops across the inductances 11 and 12 become unbalanced in a sense determined by the direction of frequency variation, and by an amount proportional to the amount of the variation, so that the rectified voltages across the load resistors 19 and 20 are rendered unequal. It will be evident, therefore, that with the cathode 18 of the diode 16 connected directly to ground the cathode 17 of the diode 15 will vary in potential above or below ground in a direction and by an amount corresponding to the direction and amount of frequency variation from the mean frequency of the oscillations supplied by the source 4.

Although the theory of operation of the inductance 8 which is common to the two series resonant circuits is not fully understood, it has been found in practice that the presence of this common inductance permits the use of a greater band width in the inductances 11 and 12 for a given overall discriminator band width, and appears also to facilitate a smoother transfer of energy between the inductances 11 and 12 as the frequency of oscillations changes within the band. Accordingly, therefore, the inductance 8 increases the band width and improves the degree of linearity of frequency response.

At Fig. 2, I have shown another embodiment of my invention in which the common return impedance in the rectifying circuits 9 and 10 is an inductance 21*a*, rather than the resistor 21 of Fig. 1. In all other respects, the circuit of Fig. 2 is similar to that shown at Fig. 1, and like parts have been assigned the same reference numerals. The operation of Fig. 2 is also essentially the same as that of Fig. 1. The band width of the circuit

of Fig. 2 is apt to be found somewhat less than that of the circuit of Fig. 1 because the inductance 21*a* is ordinarily not sufficiently constant over a wide band of frequencies to provide acceptable linearity.

I have also discovered that the circuits of Figs. 1 and 2 are operable if the common rectifier impedances 21 and 21*a* are shunted or direct connections substituted therefor. With such a low impedance common return path between the midpoints of the rectifier input and output circuits, I have obtained an increased ratio of band width to percent nonlinearity at no reduction of output. It is believed that this improved operation results from a more effective loading of the tuned circuits and the elimination of resistance divider circuits formed, for example, by the resistors 19 and 21 and the resistors 20 and 21 of Fig. 1.

While I have described only certain preferred embodiments of my invention by way of illustration, many other modifications will occur to those skilled in the art and I therefore wish to have it understood that I intend in the appended claims to cover all such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A wide band frequency discriminating circuit comprising a source of electric oscillations variable in frequency over a predetermined band of frequencies, a pair of series resonant circuits connected to said source and including a common inductive impedance and a pair of separate inductive impedances, said series resonant circuits being oppositely mistuned with respect to a predetermined mean frequency within said band of frequencies, and a pair of opposed rectifying circuits connected across said separate inductive impedances and including separate load resistors having a common terminal.

2. A wide band frequency discriminating circuit comprising a source of electric oscillations variable in frequency over a predetermined band of frequencies, a pair of series resonant circuits connected to said source and including a common inductive element and a pair of separate inductances, said separate inductances having a common terminal connected to one terminal of said common inductive element and having their remote terminals capacitively coupled for parallel resonance at a predetermined mean frequency within said band, said series resonant circuits being oppositely mistuned with respect to said mean frequency, and a pair of opposed rectifying circuits connected across said separate inductances and including separate load resistors having a common terminal, thereby to provide across remote terminals of said resistors the difference of the rectified voltages appearing across said inductances.

3. A wide band frequency discriminating circuit comprising a source of electric oscillations variable in frequency over a predetermined band of frequencies, a pair of opposed rectifying circuits having a common portion and including separate load resistors having a common terminal, separate inductive impedance elements in said rectifying circuits, a common inductive impedance connected between said source and said common portion of said rectifying circuit, and means connecting said separate inductive impedance elements and said common inductive impedance in separate series resonant circuits connected across said source and oppositely mis-

tuned with respect to a predetermined mean frequency within said band of frequencies.

4. A wide band frequency discriminating circuit comprising a source of electric oscillations variable in frequency over a predetermined band of frequencies, a pair of opposed rectifying circuits having a common inductive impedance and including separate load resistors having a common terminal, separate inductive impedance elements in said rectifying circuits, a second common inductive impedance connected between said source and said first common inductive impedance to supply oscillations from said source to said rectifying circuits, and means connecting said second common impedance and said separate impedance elements in separate series resonant circuits connected in parallel across said source and oppositely mistuned with respect to a predetermined mean frequency within said band of frequencies.

5. A wide band frequency discriminating circuit comprising a source of electric oscillations variable in frequency over a predetermined band of frequencies, a pair of opposed rectifying circuits including a common resistance and a pair of load resistances having a common terminal, separate inductive impedance elements in said rectifying circuits, a common inductive impedance connected between said source and said common resistor to supply oscillations from said source to said rectifying circuits, and means connecting said separate inductive impedance elements and said common inductive impedance in separate series resonant circuits connected across said source and oppositely mistuned with respect to a predetermined mean frequency within said band of frequencies.

6. A wide band frequency discriminating circuit comprising a source of electric oscillations variable in frequency over a predetermined band of frequencies, a pair of opposed rectifying circuits including a common impedance element and a pair of load resistors having a common terminal connected to one terminal of said impedance element, separate inductive impedances

in said rectifying circuit having a common terminal connected to the other terminal of said common impedance element, and a common inductive impedance connected between said source and the common terminal of said separate inductive impedances, thereby to form with said separate impedances and the stray circuit capacities a pair of series resonant circuits connected in parallel and tuned to resonance at spaced apart frequencies in said band of frequencies.

7. A wide band frequency discriminating circuit comprising a source of electric oscillations variable in frequency over a predetermined band of frequencies, a pair of opposed rectifying circuits including a common impedance element and a pair of load resistors having a common terminal connected to one terminal of said impedance element, separate inductive impedances in said rectifying circuits having a common terminal connected to the other terminal of said common impedance element, the stray capacity of said rectifying circuits in shunt with said separate inductive impedances being sufficient to tune said inductive impedances to a mean frequency within said band, and a common inductive impedance connected between said source and the common terminal of said separate inductive impedances, thereby to form with said separate inductive impedances and the stray circuit capacities a pair of series resonant circuits connected in parallel and oppositely mistuned with respect to said mean frequency.

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