

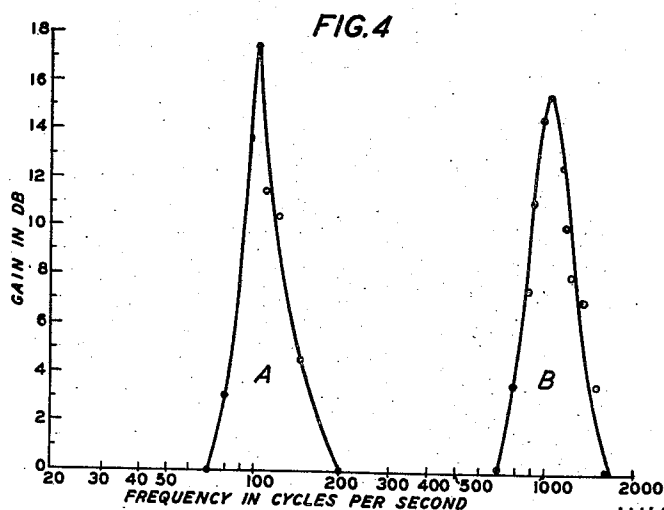
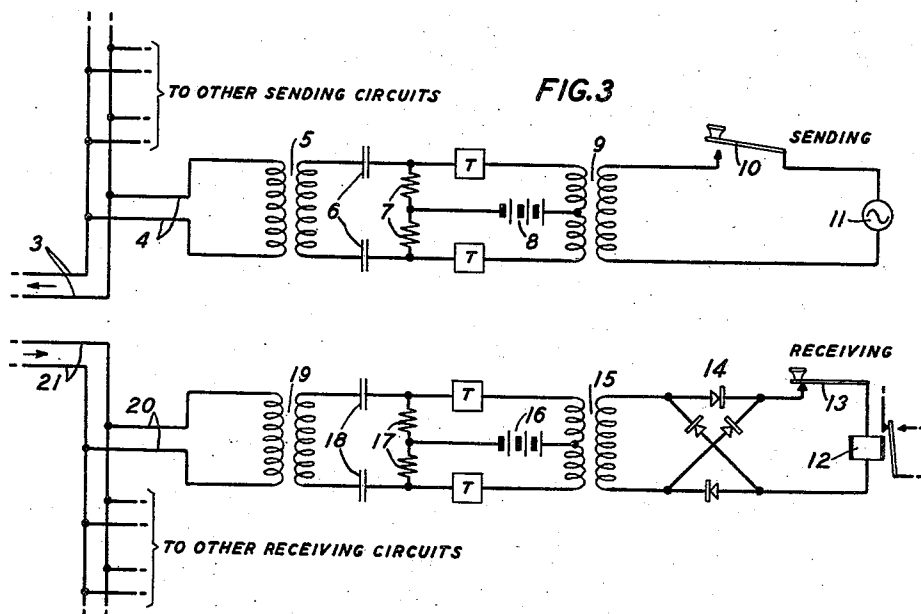
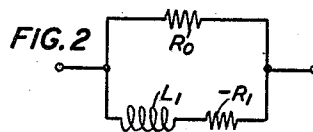
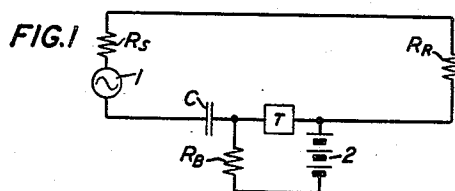
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FREQUENCY SELECTIVE AMPLIFIER

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FREQUENCY SELECTIVE AMPLIFIER

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This invention relates to amplifying systems and particularly to amplifying systems which are selective as to frequency. More particularly, it relates to the employment of semiconductors for selective amplification, and to the use of semiconductors, such as compounds of uranium which under suitably controlled conditions exhibit both negative resistance and positive reactance characteristics.

It is known that certain compounds which are ordinarily classed as semiconductors exhibit a negative temperature coefficient of resistance. This property has been discussed by Lé Blanc and Sachse in "Sachsische Gesellschaft des Wissenschaften: Berichte Über Verhandlungen", vol. 82, pages 133 and 153, 1930, and is the subject of several patents of which 1,526,139 and 2,017,011 may be taken as representative. These compounds may be employed to form circuit elements by fusing or otherwise binding platinum or other conductor leads into electrical contact with a suitable quantity of the compound.

These elements are ordinarily of comparatively high resistance. For very small currents the voltage increases with the current but as the current is increased a point of inflexion is reached beyond which the voltage decreases as the current increases and thus a negative slope is achieved. It is in this latter range that these elements function as negative resistances or amplifiers in the manner well known in the art. A usual practice is to employ a direct current potential to bring the element into the region of negative resistance, whereupon it may be inserted in a suitable alternating current circuit so as to amplify the current in that circuit.

Although this property of certain compounds of uranium, particularly uranium oxides, of boron and of other elements is well known, circuit elements constructed therefrom have not found extensive use as amplifiers for the reason that they are sluggish in action and of comparatively low gain. Now I have found that these effects are in large part the result of a reactive component in these negative resistances which appears to be a function of lag temperature change with change in current flow through the resistance, and I have further found that I can neutralize this reactive component by including in the circuit therewith a fixed reactance of opposite sign and that by this means I am able to construct a combined amplifier and band-pass filter which will provide a considerable amplification in a selected range of frequency at a very low cost. Such an equipment has application in various selective signaling systems such as voice frequency telegraph, multi-party lines and the like.

For a detailed description of the invention and

of certain preferred embodiments thereof, reference is made to the drawing in which:

Fig. 1 illustrates a basic alternating current system employing amplification means in accordance with the invention;

Fig. 2 is a diagram of the electrical equivalent of the negative resistance element employed;

Fig. 3 shows in a preferred arrangement the employment of the invention for voice frequency carrier telegraph; and

Fig. 4 shows typical gain-frequency characteristics which may be obtained in a circuit such as shown in Fig. 1.

Referring to Fig. 1 which illustrates a basic circuit of the filter amplifier of the invention, the element T is of a material whose resistance is temperature-controllable, i. e., controlled or determined by the temperature at which the element is maintained, or to which it is adjusted from some previous or initial temperature. Such an element may be of uranium oxide suitably mounted and provided with leads and may be designated as a "Thermistor," which may be defined as a device or element whose resistance, because of temperature effects, varies with the equilibrium current through it. The thermistor is biased through the current limiting resistance R_B by means of the battery 2. This combination is connected in series with the combined tuning and direct current blocking condenser C thus forming the basic group of the invention.

It has been found that the behavior of the thermistor T in an alternating current circuit is substantially equivalent to that of the network of Fig. 2 in which a negative resistance— R_i in series with the positive reactance L_1 are shunted by the direct current resistance R_0 . This thermistor, therefore, may be considered equivalent to a network whose impedance Z_T is equal to

$$-\frac{R_0(R_1 - j\omega L_1)}{(R_0 - R_1) + j\omega L_1}$$

which, in known manner, may be shown to be equal to

$$\frac{R_0[-R_1(R_0 - R_1) + \omega^2 L_1^2]}{(R_0 - R_1)^2 + (\omega L_1)^2} + j \frac{\omega L_1 R_0^2}{(R_0 - R_1)^2 + (\omega L_1)^2}$$

where

$$\frac{\omega L_1 R_0^2}{(R_0 - R_1)^2 + (\omega L_1)^2}$$

constitutes the effective inductive reactance of the equivalent network. The thermistor is shunted by the biasing resistance R_B to give a new impedance Z, equal to

$$\frac{R_B Z_T}{R_B + Z_T}$$

Provided R_B is sufficiently large and the thermistor properly biased, the impedance Z has a

negative resistance and a positive reactance component. Selective amplification is obtainable when this reactance is combined with a suitable negative reactance by proper proportioning of the condenser C. The gain may be defined as the ratio of the current flowing through the receiving resistance R_R of Fig. 1 to the current which would flow assuming that the alternating current source 1, the sending end resistance R_S and the receiving end resistance R_R remain unchanged and that the thermistor group C, T, R_B , 2 is shorted out of the circuit.

In Fig. 4 appear gain-frequency curves A and B. These are plots of gain measurements made in this manner on a circuit such as Fig. 1 and indicate amplifier characteristics which may be obtained. In obtaining the data of curve A the biasing resistance R_B was set at 29,900 ohms, the sending resistance R_S and the receiving resistance R_R at 4600 ohms each and the condenser C at 0.09 microfarad. The biasing current was 0.003 ampere. The values of the elements of the equivalent network for the thermistor were $R_0=46,000$ ohms, $L_1=8.53$ henries, $-R_1=-9050$ ohms. Curve B was obtained from the same thermistor T but the other elements of the circuit were changed as follows: $R_B=22,000$ ohms, $R_S=R_R=1195$ ohms, $C=.093$ microfarad and biasing current 0.0049 ampere. These curves illustrate the fact that a given thermistor may be employed to produce amplification in circuits having a considerable range of sending and receiving resistance and also that the effective inductance L is a function of the biasing current. In general, the frequency of resonance may be shifted and the circuit made sharply or broadly resonant by a proper proportioning of the magnitudes of the components as is well known in the use of circuits containing resistance, inductance and capacity.

A balanced thermistor amplifier is shown in Fig. 3 as a part of a voice frequency carrier telegraph system. A source of alternating current 11 is modulated with telegraph signals by the key 10. The modulated currents may be passed through a transformer 9 into the filter-amplifier circuit containing the thermistors T, T, the biasing potential 8, the biasing resistances 7, 7 and the blocking and tuning condensers 6, 6 and thence through the transformer 5 into branch 4 of transmission line 3. At the receiving end the modulated currents come in over line 21 and are divided among the several receiving circuits. Those for which amplifier filter T, 16, 17, 18 is resonant will be predominantly led into branch 20 and thence through transformer 19, the filter amplifier comprising condensers 18, 18, bias resistances 17, 17 and thermistors T, T which are biased by potential source 16. The amplified modulated signals will be imposed upon demodulator 14 via transformer 15 and the demodulated signals will then be impressed upon receiving relay 12. It is to be noted that the thermistors T, T are reversible, that is, that they function as negative resistance in the circuit regardless of the direction of current flow.

These specific and preferred embodiments are indicative of the advantages to be gained by the employment of my invention and the methods of its use. They are not to be considered to circumscribe the invention however, since it is evi-

dent that many variations and many different arrangements may be employed without departing from the spirit of the invention as defined by the following claims.

What is claimed is:

1. A selective amplifying system comprising a source of variable electric current, a work circuit, a negative resistance having a reactive component, and a reactance of opposite sign to neutralize said reactive component.
2. A system for frequency selective amplification comprising a source of variable electric current, a work circuit, and a balanced amplifier comprising balanced temperature controlled negative resistances having an effective reactive component and associated therewith reactances of opposite sign adapted to neutralize said reactive component at a desired frequency.
3. A frequency selective amplifier of the balanced type comprising an input coil having two balanced secondary windings connected in a series-aiding arrangement thus having two secondary terminals, an output coil having two primary terminals, a first secondary terminal of said input coil connected to a first primary terminal of said output coil through a temperature controlled negative resistance having a reactive component and associated with a reactance of opposite sign, the second secondary terminal of said input coil connected to the second primary terminal of said output coil through a second temperature controlled negative resistance having a reactive component and associated with a reactance of opposite sign, a battery supply circuit leading from one battery pole to the junction point of the balanced secondary windings of said input coil thence through the two branches each comprising one-half of the input coil secondary winding, one of the said negative resistances, and a battery control resistance connected to the other pole of the battery and the said reactances of opposite sign respectively adapted to neutralize the effective reactance of its associated negative resistance at a desired frequency.
4. An electric wave system comprising a compound of uranium electrically equivalent to a positive resistance shunted by an inductance and a negative resistance in series, and a condenser adapted to tune the said inductance to a desired frequency.
5. A frequency selective amplifier comprising a compound of uranium, a battery supply circuit therefor adapted to bias said compound to a condition in which it is equivalent to a positive resistance shunted by an inductance and a negative resistance in series, and a condenser adapted to tune the said inductance to a desired frequency.
6. An electric wave circuit comprising in combination a source of carrier current, and an amplifier comprising temperature controlled negative resistance having an effective reactance component and associated therewith reactance of opposite sign adapted to neutralize said reactive component at the frequency of said carrier current source.
7. An electric wave system comprising means responsive to waves of a given frequency, a negative resistance element having an effective reactive component, and associated therewith a reactance of opposite sign adapted to neutralize said reactive component at said given frequency.

ALEXIS A. LUNDSTROM.