May 7, 1929. A. J. EAVES 1,711,636

RADIO RECEIVING SYSTEM

Filed Aug. 27, 1924

Fig. 1

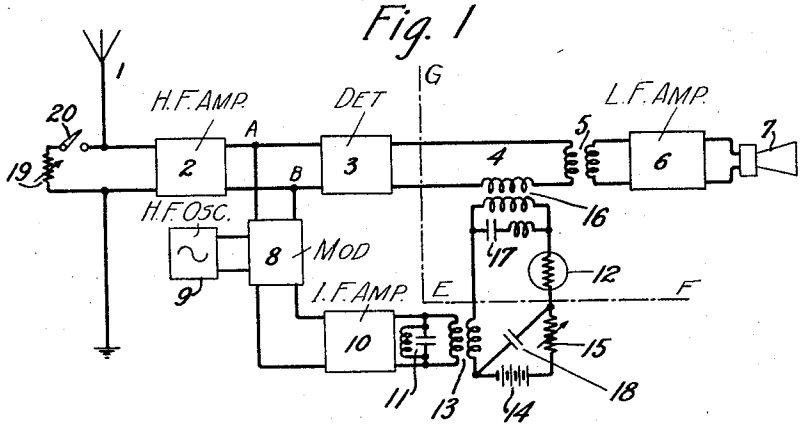


Fig. 2

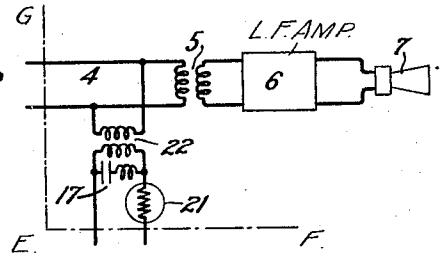
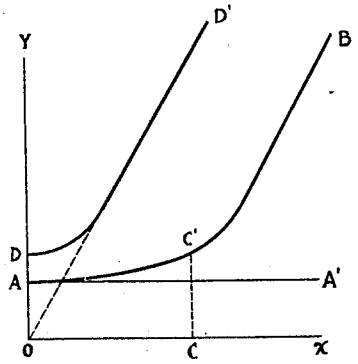


Fig. 3



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UNITED STATES PATENT OFFICE.

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RADIO RECEIVING SYSTEM.

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This invention relates to wave signaling systems and particularly to wave systems having means for compensating the effects of variations in the propagation characteristics of the wave transmitting medium.

An object of this invention is to maintain the intensity of received signals substantially independent of changes occurring in the medium through which the waves are transmitted.

In the reception of radio signals the phenomenon commonly known as fading greatly increases the difficulty of securing reliable communication, at one instant the strength of the received waves may be so great as to overload the apparatus of the system and a short time later may be so weak as to be scarcely perceptible. Under certain conditions the variations may take place slowly enough to permit compensating adjustments of the apparatus to be made by hand, but it frequently happens that the variations occur with such rapidity that manual adjustments can follow them only roughly if at all.

In the broadcasting by radio of music or other forms of entertainment the artistic value of the performance depends largely upon the variation in loudness produced by the artist. The swelling of an orchestra to fortissimo at the will of the conductor and the softening of a singer's voice to its barely audible tones must be faithfully reproduced by the broadcast receiver or the performance may be received devoid of its original artistic merit. Fading effects are an undesired modulation superimposed on that of the artist, and if these are not automatically discriminated against and eliminated the effort to separate them out and compensate them by manual adjustment may result in a reproduction in which the interpretation of the artist is entirely lost.

The present invention is particularly applicable to those systems in which the signal is transmited by a modulated carrier wave. In such systems it is sometimes convenient to regard the transmitted wave as possessing a constant frequency, that of the carrier wave, and having an amplitude that varies proportionately to that of the signal wave, or sound wave, according to which it is modulated. For the understanding of the operation of the invention, however, it is preferable to regard the transmitted wave as comprising several component waves differing in frequency. A principal component wave is the carrier wave, that being radiated from the transmitting station with an amplitude that is practically constant and received at remote stations with an intensity that varies only as the fading effect varies. The other components are the products of modulation, side frequencies differing from the carrier by an amount equal to the pitch of the signal or musical tone and having an amplitude which at a receiving station depends upon both the intensity of the impressed tone wave and the degree of attentuation in the transmitting medium.

The variation of the intensity at the receiving station of the carrier wave serves therefore as an index of the variation of the attenuation in the transmitting medium and, with suitable arrangements, compensating systems may be made to operate automatically in response to these variations. When, by such means, the variations of the attenuation in the transmitting medium are immediately compensated by corresponding variations of the amplification in the receiving set, the energy level of the detected signals varies in accordance with the intensity of the original signal wave, whereby it becomes possible to reproduce more faithfully broadcast music or speech or the like.

The novelty of the present invention does not lie in the use of the unmodulated carrier wave to gauge the fading and to effect the compensation thereof, this having been already disclosed in U. S. Patent No. 1,468,687 to H. A. Affel, granted September 25, 1923, but resides, rather, in the particular means whereby the compensation is effected so rapidly that it may follow with accuracy the most rapid changes in received waves. In accordance with the invention use is made of the variation of resistance with temperature of a conductor having a small heat capacity, to produce changes in the attenuation in the receiving circuit, the changes of temperature being made responsive to the changes in the intensity of the received carrier wave.

The nature of the invention will be more fully understood from the following detailed description and by reference to the attached drawings of which

Fig. 1 represents a receiving set embodying the invention;

Fig. 2 represents a modified form of the invention; and

Fig. 3 illustrates graphically the operation of the system of Fig. 1.

Referring to Fig. 1, incoming waves including an unmodulated component, are received upon the antenna 1 and depressed upon a high frequency amplifier 2, the input circuits of which may be tuned to resonance with the wave frequencies. From the output side of the amplifier 2, the amplified waves pass to a detector 3 in which the signals are demodulated and delivered to a low frequency circuit 4 and thence through the transformer 5 into the low frequency amplifier 6 and the signal reproducer 7. These elements constitute the normal channel for the received signals. The particular arrangement illustrated is intended to be merely representative of common receiving systems and it is not intended that the application of the invention be limited to this arrangement. At the points A and B in the input circuit of the detector 3 a parallel path branches from the normal path and includes a modulator 8 in which the received wave frequencies are stepped down by modulation with an auxiliary wave from a source 9. The source 9 may be a high frequency oscillator of any well known type such for example as that described in Patent No. 1,356,763 to Hartley issued October 26, 1920, and should be adjustable as to the frequency generated. The modulator 8 preferably employs a three-electrode space discharge tube as the modulating device, it having been shown in U. S. Patent No. 1,448,702, granted May 13, 1923 to J. R. Carson that the important products of modulation in a device of this kind possesses amplitudes proportional jointly to the amplitudes of the interacting waves. The arrangement of the modulator circuit may be in accordance with the system disclosed in the above mentioned patent.

If the carrier wave were so separated from the side frequencies that it could be selected therefrom by means of tuned circuits or sharply selective filters, the step of reducing the frequencies to a lower scale would not be necessary. At the frequencies used for radio transmission, however, it is generally impracticable to separate the carrier wave from the side frequencies and so the method is adopted of first stepping down the frequencies and then selecting from the products of lower frequency the component corresponding to the received carrier wave.

The modulation products of modulator 8 are amplified in an amplifier 10 from the output of which the reduced frequency carrier wave is selected by the parallel tuned circuit 11 and impressed upon the control resistance 12 by means of transformer 13. If the amplitude of the auxiliary wave is maintained constant the strength of the low frequency carrier wave resulting from modulation is proportional to the intensity of the received carrier wave. The secondary circuit of transformer 13 includes besides the resistance element 12 a battery 14 and variable resistance 15 by means of which a steady current may be superimposed upon the received wave in the element 12. It also includes a transformer 16 through which the circuit is coupled to the low frequency signal circuit 4 in the normal receiving channel. A tuned circuit 17 resonant at the frequency of the wave impressed by the transformer 13 effectually prevents that wave from entering the normal receiving channel, and a condenser 18 of large capacity offers a path of low impedance around the resistance 15 and the battery 14 to both low frequency and high frequency waves.

The resistance element 12 preferably consists of an ordinary tungsten filament incandescent lamp, the heat capacity of an element of this type being so small that its temperature, and therefore its resistance, readily follows rapid changes in the intensity of the impressed waves. An alternative form that may also be used is the Nernst filament consisting of a fine iron wire enclosed in an atmosphere of hydrogen. This possesses the advantage of having a very strong variation of resistance with temperature but on account of its greater heat capacity due to the hydrogen atmosphere, it is less rapid in its action than the tungsten lamp filament.

The operation of the system is as follows: Incoming waves comprising a carrier wave having a frequency, for example, of 500,000 cycles per second and side frequencies which may extend through a range of 5000 cycles per second on each side of the carrier are received upon antenna 1 and amplified in the high frequency amplifier 2. In the branch circuit the frequencies of the received waves are stepped down in the manner already described so that a new carrier wave is produced having a superaudible frequency, for example 20,000 cycles per second the source 9 being arranged to produce a frequency of 480,000 cycles per second for this purpose. This carrier wave is separated from its accompanying side bands by means of tuned circuit 11, and its amplified energy is dissipated in the resistance element 12. The resistance of the element 12 is thus caused to increase, the amount of the increase depending upon the strength of the impressed 20,000 cycle wave, and therefore upon the strength of the received carrier wave. Through transformer 16, the resistance of the element 12 is effective in the low frequency circuit 4 of the normal receiving path, the impedance of which is therefore caused to increase or decrease in accordance with the intensity of the received carrier wave. The gain of the receiving system is thus decreased as the received carrier wave increases in intensity, whereby the effects of fading or of variable attenuation in the transmitting me-

dium are more or less completely compensated. The tuned circuit 11, which has a very low impedance at signal frequencies, and the condenser 18 effectually short circuit the other elements of the coupled circuit so that the impedance of the element 12 alone is effective in the normal signal channel.

For perfect regulation it is necessary that the impedance of the circuit 4 should increase in direct proportion to the intensity of the received carrier wave. This condition is difficult to achieve but when the transformer 16 is so proportioned that the transformed impedance of the element 12 is a large proportion of the total impedance of the circuit 4, and when the element 12 is so conditioned that its resistance changes rapidly with the strength of the current flowing in it, a good approximation to the ideal condition is secured. It is well known that the resistance of a metallic filament in vacuo increases at a more rapid rate than the current flowing through it, but for small values of the current the actual increase is very small. If, however, the filament is heated by means of a steady current to an initial state, which may be well below the point of visible radiation, a small superimposed current will produce a large change in its resistance. This is illustrated in Fig. 3 in which the quantities plotted refer to the circuit of Fig. 1. The abscissæ represent the effective values of the carrier wave current flowing in the resistance 12 and the ordinates, the total resistance of the low frequency circuit 4 in the normal receiving channel.

The horizontal line AA′ represents the fixed impedance of the circuit and the curved line AB represents the total resistance that would be present if the only current flowing through the resistance were that due to the impressed wave. If, however, a steady current corresponding to the abscissa OC is passed through the resistance from the battery 14, the increments of current due to the impressed wave produce large resistance changes. The curve DD′ which corresponds to the curve AB with the origin of the axes transferred to the point C represents the type of variation of the receiving circuit impedance with respect to the impressed wave intensity that is obtained under these circumstances. It is not intended that these curves represent the actual values for the circuit illustrated, but rather that they indicate the nature of the approximation to the ideal case cited above. In practice the proper value of the steady current may be determined experimentally. A simple method of doing this is to introduce a controlled fading effect in the high frequency amplifier 2 and to adjust the steady current by means of the variable resistance 15 until a minimum change of signal strength is noted as the artificial fading effect is varied. In Figure 1 a variable resistance 19 which may be connected in shunt to the input of amplifier 2 by switch 20 furnishes a means for producing the controlled fading effect.

In Fig. 2, which represents a modified arrangement of that part of the circuit of Fig. 1 above the dotted line EF and to the right of the dotted line EG, the control resistance 21 is connected effectively by transformer 22 to bridge the low frequency circuit 4 and to shunt the input of the amplifier 6. In this modification of the invention the control resistance may be a carbon filament incandescent lamp or other type of element having a strongly negative temperature resistance variation. The operation is analogous to that of Fig. 1; an increase of the current in the resistance element results in a decreased resistance and therefore in an increased attenuation in the normal receiving channel due to the increased shunting effect. The advantages of the initial steady current in the control resistance are also realized in this modified arrangement and the procedure for determining the optimum value of that current is identical with that described in connection with Fig. 1.

What is claimed is:

1. In a receiving system for modulated waves, means for controlling the intensity of the detected signals comprising a resistance element whose resistance varies with changes in temperature, means for coupling said element in said system so as to be effectively included as part of the impedance offered to the detected signal currents, means for establishing a flow of direct current through said element and means for superposing upon said element high frequency currents of amplified intensity corresponding to the amplitude of the received waves, whereby the temperature of said element is controlled in accordance with the strength of the received waves.

2. A receiving system for signals transmitted as side waves of a carrier wave, comprising a normal path for the detection and reproduction of said signals, a second path having means included therein for the production of energy in proportion to the energy of the received carrier wave, a resistance element in said second path adapted to receive and dissipate said energy, and having a resistance variable with respect to the rate of dissipation, and means for causing said variable resistance to enter into the impedance of said normal path.

3. In a radio receiving system adapted to receive signals transmitted as side waves of a carrier wave, means for reducing the fading of received signals comprising a resistance element having resistance variable with respect to the rate of energy dissipation therein, means for deriving from the received carrier wave a lower frequency wave of proportionally related amplitude and increased energy,

means for impressing said derived wave upon said resistance, and means for causing said resistance to enter into the impedance presented to the received signals.

4. A radio receiving system adapted to receive signals transmitted as side waves of a carrier wave, comprising a normal path for the detection of received waves, a second path parallel to said normal path, a resistance element having a positive temperature resistance coefficient connected effectively in series with both of said paths, means in said second path for producing wave energy proportional to the energy of the received carrier wave, means for impressing said energy upon said element to increase its temperature, and means for controlling the initial temperature of said element whereby said impressed energy produces a large increase in the resistance thereof.

5. A radio receiving system adapted to receive signals transmitted as side waves of a carrier wave, comprising a normal path for the detection of received waves, a circuit for the detected signal currents included in said path, a resistance element of low heat capacity and having a positive temperature resistance coefficient effectively connected in series in said circuit, a source of wave energy controlled by the received carrier wave to produce energy in proportion to the energy thereof, means for impressing said energy upon said element, and means for controlling the initial temperature of said element whereby the impedance of said element is made to increase substantially in proportion to the intensity of the received carrier wave.

In witness whereof, I hereunto subscribe my name this 26th day of August, A. D. 1924.

AUGUSTUS J. EAVES.