

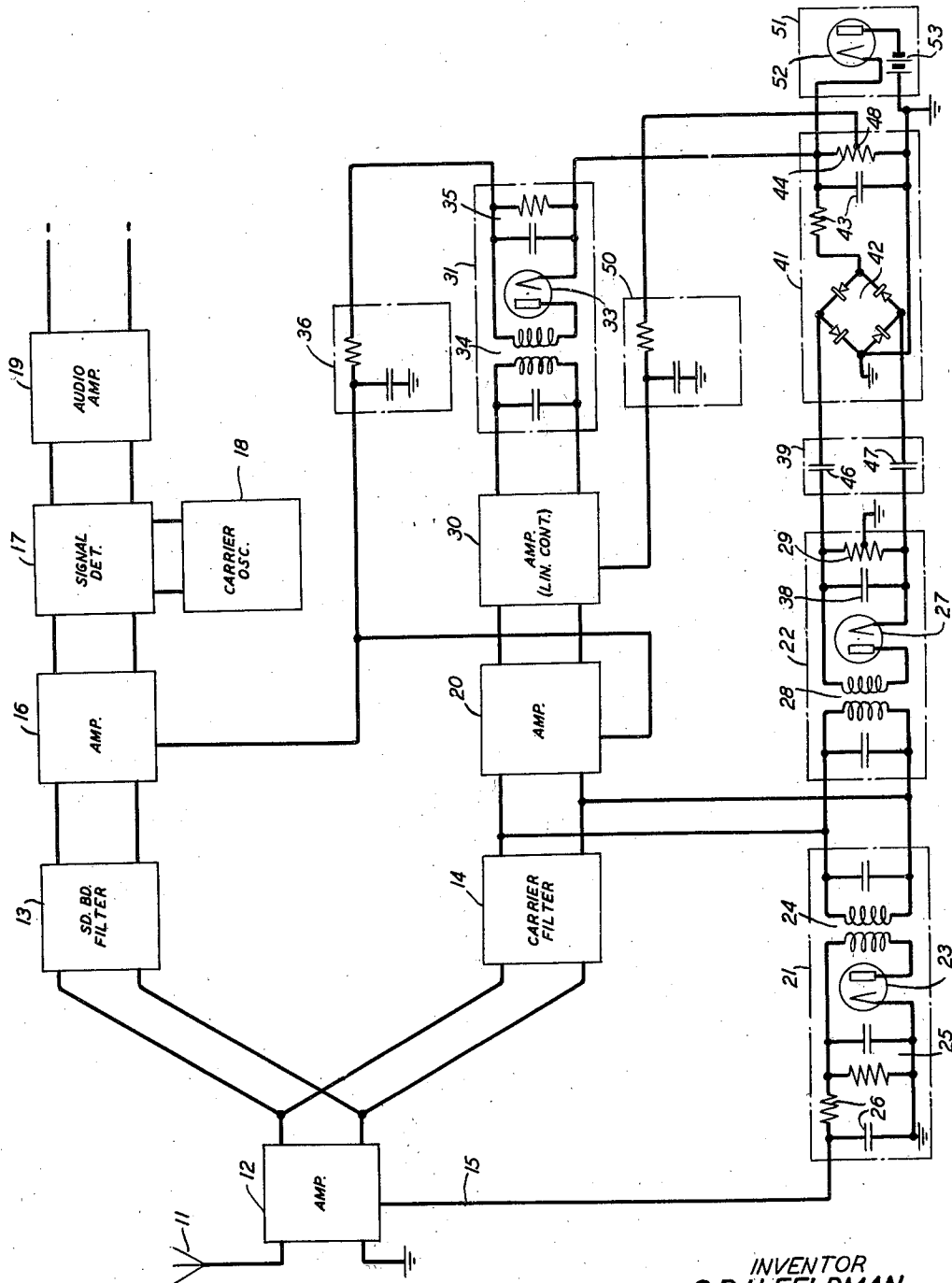
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RADIO RECEIVER

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RADIO RECEIVER

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This invention relates to the reception of radio waves and particularly to methods and systems for overcoming the effects of fading.

One problem which has long been recognized in the reception of radio waves is that of fading. By fading is meant the variation with time in the strength of the radio field at a receiving point. This phenomena is particularly marked in the case of the use of short waves for transmission over long distances. One method which is widely used for overcoming the effects of fading is that of automatic volume or gain control. In that method of operation the gain of the radio receiver is automatically controlled in response to the field strength so that the output of the receiver is maintained comparatively constant despite the fading variations in the field strength at the receiver.

An object of the invention is to improve the methods and circuits for automatic volume control.

In the more common type of automatic volume control system the automatic regulation of the gain of the receiver amplifiers is effected in response to the amplitude of the received carrier wave. One important advantage of this type of system is that the control is continued during non-modulation periods so that the receiver is always prepared for modulation when it begins.

However, the effect of fading is not always to vary the field strength at all frequencies in the signal band simultaneously. The phenomenon of a different variation in the strength of various frequency components of the received wave band is known as selective fading. For wave bands of sufficient width for telephone communication practically all fading is selective. When the fading is only slightly selective the control based on the carrier will provide a regulation which in general is satisfactory to compensate for the effects of the fading. On the other hand, under the conditions of highly selective fading the compensation dictated by the carrier may often be opposite to that required by the fading conditions of the side-band. Accordingly, there may result blasting and other disturbances which are as troublesome as those caused by fading itself. The difficulties encountered with highly selective fading have been found to be considerably greater in the case of single side-band transmission than for double side-band transmission.

Another factor which comes into play in the operation of automatic volume control systems is the time lag or delay in the operation. This

is not deliberately introduced into the system but is an essential characteristic of the filter networks which it has been found desirable to employ in order to reduce the extent of the control action for fast fading.

It has been observed that in the case where the fading is only slightly selective the rate of fading is typically slow. Under such circumstances the carrier is fairly representative of the effective side-band level and automatic volume control responsive to the carrier level provides adequate correction for the fading effects. Also under these conditions of slightly selective fading, more gain control action is usually required than under the conditions of highly selective fading where the side-band amplitude distortion is so fine grained that the level, averaged over the side-band, remains fairly constant.

In accordance with a feature of the present invention, it is proposed to make the automatic volume control of a radio receiver fast-acting under all conditions and, in order to meet the requirements for rapid fading, to make the degree or stiffness of the control dependent upon the rate of fading so that for rapid fading the degree of control is low. In effect a fairly constant amplification is maintained during such periods of fast fading, which is satisfactory for the reason that under such conditions the average side-band level is usually fairly constant, as was just pointed out.

The accompanying drawing is a schematic circuit diagram of a radio receiver embodying one form of the invention.

This receiver is adapted for the reception of radio waves comprising a single side-band accompanied by carrier of normal or reduced amplitude. (A generally similar circuit arrangement could be used for double side-band reception.)

The radio waves received in the antenna **11** are applied to the input of an amplifier **12** which may comprise one or more amplification stages. Also, in the case of short wave operation to which the invention is particularly adapted, the amplifier **12** may consist of the well-known superheterodyne system comprising a frequency converter and intermediate frequency amplifier stages.

The amplifier tubes of the amplifier **12** are arranged to have their gain regulated by the direct current voltage supplied through the connection **15** in the manner of the conventional automatic volume control system. This preliminary control is designed to give only a rough leveling off

of the output level of amplifier 12 and while helpful to the purposes of the invention is not essential thereto.

The output of the amplifier 12 is fed to two parallel paths, one including the side-band filter 13 and the other, the carrier filter 14. The side-band selected by the filter 13 is amplified in the amplifier 16 and supplied to the signal detector 17 where it is demodulated by combination with the carrier oscillations from oscillator 18. The resultant signal is amplified in the audio amplifier 19.

In the other path, the carrier wave selected by the highly selective carrier filter 14 is supplied to three parallel paths. One of these comprises the amplifier 20. The other two comprise the automatic volume control rectifiers 21 and 22 respectively. The paths leading from the filter 14 to the rectifiers 21 and 22 may include one or more stages of amplification but these are not shown in the drawing for the reason that they are not essential to the understanding of the invention.

The automatic volume control rectifier 21 comprises a diode rectifier tube 23 connected in series with the secondary winding of an input transformer 24 and a load network 25. The direct current voltage developed across the resistor of the load network 25 is supplied through the resistance-capacity filter 26 and lead 15 to the control grids of the amplifier 12 for regulating the gain thereof in the well-known manner of automatic volume control. The resistance-capacity filter 26 causes this control to operate slowly, preferably being given a time constant of the order of several seconds. The effect of the control of the gain of amplifier 12 is to provide a slow-acting automatic volume control to maintain the level of the output of amplifier 12 within about ± 10 decibels for fading encountered in normal operation.

The special gain (or volume) control of the present invention is applied to the amplifiers 16 and 20 which preferably have similar operating characteristics. This gain control is always fast-acting but has its stiffness, i. e., degree of control, varied in accordance with the rate of fading. The system and method of obtaining such a gain control action will now be described.

The output of amplifier 20 is supplied through a control amplifier 30 to a rectifier 31. The amplifier tube used in the amplifier 30 has a linear grid characteristic, that is, of the sharp cut-off type as distinguished from the remote cut-off (variable μ) or exponential grid types employed in the automatic gain control amplifiers.

The rectifier 31 comprises a diode rectifier tube 33 which is connected in series with the secondary of an input transformer 34 and a load resistor 35. The direct current voltage developed across the resistor 35 is applied through the time constant filter 36 to the grids of the tubes of the amplifiers 16 and 20 to regulate their gain. The network 36 has a low time constant of the order of 10 milliseconds so as to make this gain control fast-acting.

The stiffness of the rapid gain control is varied by two means: first, by a reduction of the voltage input to rectifier 31 and consequently of the voltage across resistor 35 by the control amplifier 30 and second, by the insertion of a steady compensating bias in series with the bias from resistor 35. This compensating bias is obtained from the voltage drop across resistor 44 in rectifier 41. This same rectifier 41 also controls the amplifier

30 and operates to produce a direct current bias across resistor 44 which is proportional to the fading rate. The circuit for accomplishing this action will now be described.

The rectifier 22 comprises a diode rectifier tube 27 which is connected in series with the secondary of the transformer 28 and the load resistor 29. As previously described, the input to rectifier 22 is taken from the carrier filter 14. As a result the voltage developed across resistor 29 will be a rectified sample of the uncontrolled carrier voltage. This voltage is supplied through the high-pass filter 39 comprising the series condensers 46 and 47 to the rectifier 41. The filter 39 is of a type having a sloping characteristic as distinguished from a sharp cut-off. Let us consider the voltage across resistor 29 as being made up of two components, one a direct current component representing the amplitude of the carrier and the other an alternating current representing the amplitude variations of the carrier. The direct current component is suppressed by the filter and the input to the rectifier 41 will be only the part representing the variations of the carrier. Because of the sloping characteristic of the filter the input to the rectifier will increase as the rapidity of the carrier variation increases.

Rectifier 41 comprises a bridge type rectifier 42, the output of which is connected through the resistance-capacity filter 43 to the load resistor 44. The voltage across resistor 44 will therefore be proportional to the rate of variation or fading of the carrier. The polarity of rectifier 42 is such that the ungrounded terminal of resistor 44 is negative with respect to the grounded terminal.

A voltage limiter 51 is connected in shunt to the load resistor 44. This limiter comprises a diode tube 52 connected in series with a biasing battery 53. For all voltages across the resistor 44 less than the voltage of the battery 53 the diode 52 is non-conducting. For any higher voltages the diode acts as a short circuit thus limiting the voltage to such a maximum value. The limiter 51 is required to prevent the voltage across resistor 44 from exceeding the value of the voltage across resistor 35 under the conditions in which the voltage resistor 44 is zero.

A tap 48 on resistor 44 is connected to the control grid of amplifier 30 through the resistance-capacity filter 50 which has a low time constant. By this means the gain of this amplifier is regulated in accordance with voltage output of rectifier 41. Thus as the rate of fading increases, the voltage across resistor 44 increases and the gain of amplifier 30 is reduced which in turn reduces the input to the rectifier 31 and consequently the voltage across the resistor 35. However, the control voltage supplied to amplifiers 16 and 20 is not the voltage across resistor 35 alone but rather the sum of the voltages across resistors 35 and 44. At the same time that the voltage across resistor 35 is being reduced by the action on the control amplifier 30 the voltage across resistor 44 is increased by the same factors which caused the reduction of the gain of amplifier 30.

As pointed out above, the amplifier 30 is of the type in which the gain varies linearly with grid voltage. Consequently, the circuit may be so adjusted that the sum of the voltages across resistors 35 and 44 remains constant. More strictly speaking the amount of the reduction of the voltage across resistor 35 produced by the action on the control amplifier 30 is exactly compensated by the voltage across resistor 44 added to the total control voltage for amplifiers 16 and 20.

The operation described immediately above with respect to the control action effected through the rectifier 41 is of course in response to the variations in the carrier and independent of the level of the incoming carrier. Simultaneously with this action there is a variation of the voltage across resistor 35 in response to the received field strength. This variation is instantaneously reflected in the regulation of the gain of the amplifiers 16 and 20 since the filter circuit 36 has a very low time constant (or may be eliminated entirely). The operation of the circuit is to remove the time lag in the automatic gain control action.

In another way of viewing the action of the complete circuit, the action of rectifier 31 is to provide a rapidly acting regulation of the gain of amplifiers 16 and 20, which action is very strong under conditions of slow variations as the amplifier 30 will be operating in the range of its maximum gain. On the other hand, when the fading is rapid the gain of the amplifier 30 is reduced so that the strength of the gain regulation action is reduced. However, when such stiffness reducing action comes into play the operation is not simply to reduce the gain regulating voltage but rather to substitute for the varying voltage a fixed voltage from resistor 44. Thus, when the fading begins to vary rapidly the gain of the amplifiers 16 and 20 is maintained at the value dictated by the field strength level at such instant. This provides adequate control since under conditions of rapid fading the average side-band level is generally fairly constant.

The degree to which the regulating action is shifted from a response to variations in field strength is of course dependent on the rate of such variations. For slow fading, before the rectifier 41 comes into action, the voltage across resistor 35 directly follows the variations in field strength. At the other extreme when the rate of fading is a maximum and the amplifier 30 is substantially blocked the regulating action is completely replaced by the fixed voltage across resistor 44. For intermediate conditions there will be a varying division of the action between the varying control voltage from resistor 35 and the fixed bias from resistor 44. The circuit is very flexible and by proper adjustment the desired interplay of these controls to meet the conditions and results of a particular situation may be brought about.

Other variations in the circuit to give other desired results will be readily suggested to those skilled in the art. For example, an asymmetrical action may be achieved by opening the connections at one of the condensers 46 or 47, depending on the polarity of the bridge rectifier 42. In this way the stiffness reduction may be made greater for carrier decreases than for carrier increases. Another variation which may be made is to make the condenser 38 in shunt to resistor 29 of large capacity. By so doing, the fine grain of the fading may be averaged out and the stiffness reducing action will vary with the average fading rate.

What is claimed is:

1. A receiver for modulated radio waves comprising filter means for separating the received carrier component from the received side-band components, means for amplifying the side-band components of the received waves, means for controlling the gain of the amplifying means in accordance with the amplitude of the received carrier component, and means for regulating the

degree of such control in accordance with the rate of variation of the amplitude of the separated carrier component.

2. A receiver for modulated radio waves comprising filter means for separating the received carrier component from the received side-band components, means for amplifying the side-band components of the received wave, means substantially instantaneously responsive to fading variations in the received carrier component for controlling the gain of the amplifying means in accordance with the amplitude of the received carrier component, and means for regulating the degree of such control in accordance with the rate of variation of the amplitude of the separated carrier component in such a sense as to make the degree of control inversely proportional to the rate of variation of the amplitude of the received carrier.

3. A radio receiver comprising an amplifier for the received signals, means for separating the received carrier from the received signals, an amplifier for the separated carrier, means for producing a direct current voltage proportional to the amplitude of the amplified carrier, means for controlling the amplification of both the received signals and the separated carrier in accordance with said direct current voltage, and separate means for controlling the gain of said amplifier for the separated carrier in accordance with the rate of variation of amplitude of the received carrier whereby the amplitude of said direct current voltage is regulated.

4. A radio receiver in accordance with claim 3 including additional means for controlling the amplification of both the signal and separated carrier in accordance with a voltage proportional to the rate of variation of the received carrier.

5. A radio receiver comprising amplifying means for amplifying both the side-band and carrier components of the received wave, means for producing a voltage proportional to the amplitude of the amplified carrier component, means for producing a voltage proportional to the rate of variation of the received carrier component, means for regulating the gain of said amplifying means in response to the sum of said voltages, and means for regulating said means for producing a voltage proportional to the amplitude of the amplified carrier component in response to said voltage proportional to the rate of variation of the received carrier.

6. A radio receiver comprising amplifying means for both the side-band and carrier components of the received wave, means for producing a voltage proportional to the amplitude of the amplified carrier component, means for producing a voltage proportional to the rate of variation of the amplitude of the received carrier component, means for regulating the gain of said amplifying means in response to the sum of said voltages, and means responsive to said voltage proportional to the rate of variation of the amplitude of the received carrier component for producing variations in the voltage proportional to the amplitude of the amplified carrier component substantially equal and opposite to said voltage proportional to the rate of variation in the amplitude of the received carrier.

7. A radio receiver comprising means for amplifying the received side-band and carrier components, means for rectifying the amplified carrier component, means for controlling the gain of the amplifying means in inverse proportion to

the amplitude of the output of said rectifying means, means for producing a voltage proportional to the rate of variation of the received carrier component, means for regulating the output of the rectifying means in inverse proportion to said voltage proportional to the rate of the variation of the received carrier component, and means for further controlling the gain of said amplifying means in accordance with said voltage proportional to the rate of variation of the received carrier.

8. A radio receiver in accordance with claim 7, in which said regulation of the output of the rectifying means and said further control of the gain of said amplifying means are so proportioned as to substantially compensate each other in their effect on the gain of said amplifying means.

9. The method of radio reception comprising amplifying the received waves, controlling the gain of said amplification in inverse proportion to the amplitude of the received carrier and regulating the degree of such control in proportion to the rate of fading variation of the amplitude of the received carrier to the exclusion of signal modulations thereof.

10. The method of radio reception comprising separating the carrier component from the side-band components of the received waves, amplifying both components of the received waves, regulating the gain of said amplification in accordance with the amplitude of the received carrier and simultaneously further regulating the gain of said amplification in accordance with the rate of variation of the separated carrier component.

11. A receiver for modulated radio waves comprising filter means for separating the carrier and side-band components of the received wave

from each other, means for amplifying the separated side-band components of the received waves, means for producing a voltage proportional to the amplitude of the separated carrier component, means for producing a voltage proportional to the rate of change of the separated carrier component, and means for simultaneously controlling the gain of said means for amplifying the separated side-band components in accordance with both of said voltages.

12. The method of radio reception which comprises separating the carrier component from the side-band components of the received waves, amplifying both components of the received waves, producing a first direct current voltage proportional to the amplitude of the separated carrier component of the received wave, producing a second direct current voltage proportional to the rate of variation of said separated carrier component and regulating the gain of said amplification in accordance with both said first and said second direct current voltages.

13. The method of radio reception which comprises amplifying the received waves, producing a first direct current voltage proportional to the amplitude of the carrier component of said received waves, producing a second direct current voltage proportional to the rate of change of amplitude of the said carrier component, regulating the production of said first voltage in accordance with said second voltage, and regulating the gain of said amplification in accordance with said first voltage.

14. The method of radio reception in accordance with claim 13 which comprises further regulating the gain of said amplification in accordance with said second voltage.

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