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TRANSMISSION REGULATION

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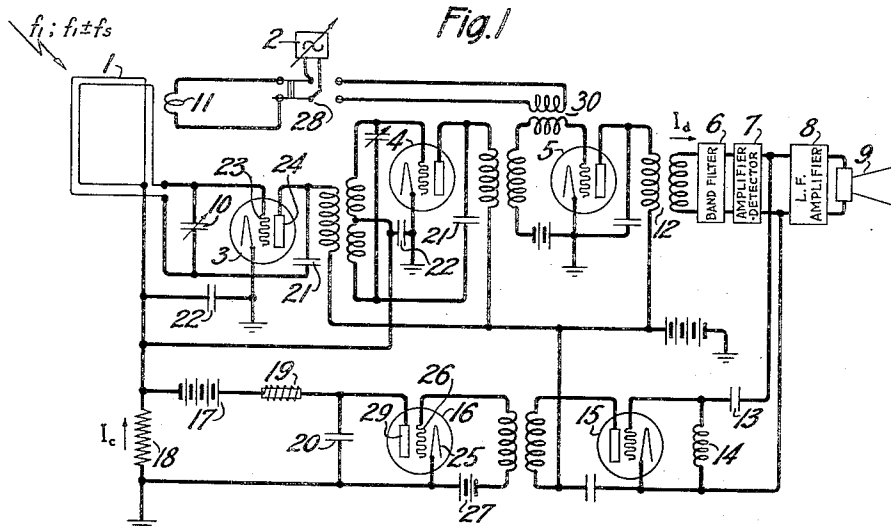


Fig. 2

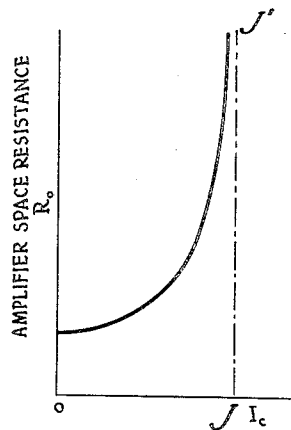
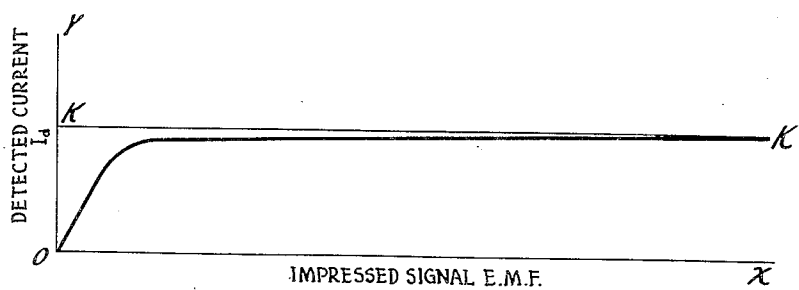


Fig. 3



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TRANSMISSION REGULATION.

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This invention relates to radio receiving systems and more particularly to methods of and means for controlling the intensity of received signals at a uniform level.

One object of the invention is to improve the constancy of the over-all transmission equivalent in radio communication systems.

It is well known that radio signaling waves are subject to extremely variable attenuation and that the strength of the received signals may vary so greatly as to make it difficult and even impossible at times to obtain satisfactory communication. These variations may be due to the regular changes between day and night conditions or they may be the much more rapid changes which are commonly known as "fading" effects. Slow changes of the former kind may be compensated by manual adjustment of the sensitivity of the receiving system, but compensation of the much more rapid fading effects requires some form of automatic adjustment.

To maintain a uniform transmission equivalent in a radio system it is necessary that any change in the attenuation of the medium be immediately offset by an opposite change in the gain characteristic of the receiving system. Methods of securing this result have been proposed by Espenschied and Bown in U. S. Patent No. 1,447,773, issued March 6, 1923, and by Affel in U. S. Patent No. 1,468,687, issued September 25, 1923.

The methods disclosed in these patents consist in radiating along with the signal wave a "pilot" wave of constant amplitude, and employing at the receiving station currents corresponding to this wave to control the sensitivity of the receiving system. The control apparatus, including mechanical elements, is so arranged that if the received pilot wave diminishes in intensity the sensitivity of the receiving system is increased by a corresponding amount and vice versa.

The pilot wave, being free from signal variations, is modified only by the attenuation of the transmission medium and therefore the control of the receiver gain is responsive only to changes in the attenua-

tion of the medium. In most communication systems the signal is transmitted as a modulated carrier wave, which may be considered as a wave of single frequency and varying amplitude or alternatively as a group of waves including a constant wave of the carrier frequency and side waves representing the signal. It is therefore unnecessary to provide a special pilot wave as the carrier wave, when separated from the side waves, is satisfactory for the purpose. A transmitting system suitable for this method of transmission is described in U. S. Patent No. 1,442,147, January 16, 1923, to Heising.

By the present invention an improved means is provided for controlling the sensitivity of the receiving system in accordance with the intensity of the received carrier or pilot wave. The control is effected without the intervention of any mechanical device and may be made to respond accurately to and to compensate changes in the transmitting medium having periods of less than one fiftieth of a second.

In the detailed description which follows the invention will be described as applied to radio telephony for the reason that the need is greatest in that field. It is to be understood, however, that it may be applied equally well to any type of carrier wave system regardless of the nature of the medium of transmission.

Fig. 1 of the drawings shows a receiving system in which the invention is embodied;

Fig. 2 shows a special characteristic curve of an amplifier which is adapted to illustrate the operation of the invention; and

Fig. 3 is the operating characteristic curve of the receiving system of Fig. 1.

The receiving system of Fig. 1 is of the double detection or super-heterodyne type in which an intermediate frequency carrier wave is produced by demodulation of the incoming wave with an auxiliary wave locally generated. The incoming waves are received by the loop antenna 1 which may be tuned to resonance by means of condenser 10. The auxiliary wave is supplied from a local source 2 and is impressed upon the

high frequency circuit through a small loop 11 which is coupled to the receiving loop 1. Two stages of high frequency amplification are provided by the tandem connected space discharge amplifiers 3 and 4, both the incoming waves and the auxiliary waves being amplified thereby. The first stage of detection occurs in the space discharge demodulator 5 from the output of which the demodulation products are delivered through a transformer 12 to the band-pass filter 6.

The function of filter 6 is to separate out and transmit only the intermediate frequency waves corresponding to the difference between the incoming wave frequencies and the auxiliary wave frequency. It is preferable that the intermediate frequency waves should occupy a band centered in the neighborhood of 50,000 cycles per second, the width of the band being made sufficient to include the intermediate frequency carrier and all side frequencies necessary for the proper reproduction of the signal. The filter may be constructed in accordance with the methods and formulæ disclosed in U. S. Patent No. 1,227,113, issued May 22, 1917, to G. A. Campbell.

The selected intermediate frequency band is amplified in the amplifier-detector 7, in which the final step of detection to produce the low frequency signal currents also takes place. The low frequency currents are delivered to an amplifier 8 and the amplified current is supplied to the signal reproducer 9, which is illustrated as a loud speaking telephone.

The amplifier-detector 7 and the amplifier 8 are indicated only in conventional form, the particular type and arrangement used being unimportant, since any well known devices adapted to perform the desired functions may be used.

The local auxiliary wave source 2 should be adjustable so that the frequency of the intermediate carrier wave and the associated side frequencies may be within the range selected by the filter 6. A suitable form of auxiliary source is the space discharge oscillator disclosed in U. S. Patent No. 1,356,763, issued October 26, 1920 to R. V. L. Hartley.

The control current by which the sensitivity of the receiver is regulated is selected from the output of the amplifier-detector 7 by the resonant circuit 13, 14, connected in shunt to its output circuit, which is tuned to the frequency of the intermediate carrier wave. Its voltage after being amplified in the space discharge amplifier 15 is impressed upon the space discharge detector 16 in the output of which it produces a steady direct current. The control electrode 26 of the detector is so polarized by the battery 27

that little or no space current flows normally; consequently in accordance with the well known characteristics of space discharge detectors, an alternating E. M. F. impressed upon the control electrode produces a direct current in the space path which increases as the impressed E. M. F. increases.

The output circuit of the detector 16 includes the space discharge path between the anode 29 and the cathode 25, a separate space current source 17 and a fixed resistance 18. The cathode and one terminal of the resistance 18 are connected together at ground potential. Choke coil 19 and condenser 20 serve to prevent the flow in resistance 18 of any alternating current corresponding to the impressed intermediate frequency wave.

For reasons that will be explained later, the high frequency amplifiers 3 and 4 are provided with balancing capacities 21 to neutralize the coupling between the output and the input circuits of the amplifiers due to the internal electrode capacities.

In the first high frequency amplifier, the cathode is connected through a relatively large capacity 22 to the mid-point of the receiving loop, the potentials of the end terminals of which are therefore balanced with respect to the cathode and are of opposite sign. One terminal of the loop is connected to the input or control electrode 23 of the amplifier and the other is connected through the balancing condenser 21 to the anode 24. The capacity of the condenser 21 is substantially equal to the direct capacity between the electrodes 23 and 24. By this means, any current that might be transmitted directly from the input to the output of the amplifier through the electrode capacity is neutralized by an equal and opposite current transmitted through the balancing condenser.

The circuit of the second stage is similar and operates in a similar manner. The system of neutralization described has been disclosed in U. S. Patent No. 1,334,118, issued March 16, 1920 to C. W. Rice.

The control of the sensitivity of the system is secured by causing the rectified output current of the detector 16 to modify the control electrode potentials of the amplifiers 3 and 4. The cathodes of these amplifiers are connected to ground, and the control electrodes are connected to the ungrounded terminal of resistance 18, whereby they are caused to assume the potential of this point. This potential is determined by the current flowing in the resistance.

As current can flow only in the direction from ground to the anode of the detector 16, the fall of potential across the resistance 18 is such as to impress a negative potential

upon the amplifier control electrodes. An increase of the current in the resistances 18 will increase the negative potential applied to the control electrodes of the amplifier and in consequence will reduce the amplifier space currents. This is equivalent to increasing the internal resistance of the amplifiers and is effectual in reducing their over-all amplification. It follows then that an increase in the intensity of the incoming wave, by producing an intermediate frequency carrier wave of larger amplitude, causes an increased current to flow in the resistance 18, and thereby reduces the sensitivity of the receiving system.

The relationship between the space path impedances of the amplifiers 3 and 4 and the polarizing potentials of their control electrodes is shown qualitatively by the curve in Fig. 2. The ordinates are proportional to the space path impedance; the abscissæ are proportional to the steady current I_c flowing in the resistance 18, and therefore to the polarizing potentials applied to the control electrodes of the amplifier. The vertical dotted line JJ' corresponds to the potential that is just sufficient to reduce the space current to zero, the space path impedance becoming infinite under this condition.

The detected current I_c cannot exceed the value corresponding to the abscissa OJ; since it requires for its production that some part of the incoming wave be repeated by the amplifiers and this cannot take place if the amplifiers are blocked. A continually increasing intensity of the incoming wave may cause the detected current to approach indefinitely close to the limiting value, but it can never attain such a value that the amplification of waves by the amplifier is actually stopped. The detected current will therefore be substantially constant for all intensities of the incoming wave greater than some low value depending on the initial sensitivity of the system. Since the detected current remains constant, it follows that the intermediate frequency carrier wave from which it is produced must also remain constant.

The relationship between the current intensity of the intermediate frequency carrier wave and the E. M. F. of the incoming signal carrier wave is shown by the curve of Fig. 3. The abscissæ are proportional to the E. M. F. of the incoming carrier wave measured at the input terminals of the amplifier 3, and the ordinates are proportional to the current intensity denoted by I_a , of the intermediate frequency carrier wave at the point where it enters the band filter.

The horizontal line K, K' represents the limiting value that the current I_a may approach, but which it cannot equal or exceed. The ordinate OK is proportional to the in-

tensity that produces the limiting value OJ in Fig. 2, of the control current I_c . The slope of the curve at the origin of the coordinates is proportional to the initial sensitivity of the system; namely the sensitivity that would be obtained if the control system were made inoperative, or the sensitivity that is obtained for such low intensities of the incoming wave that the effect of the control is negligible. Obviously, as the initial sensitivity of the system is increased, the control system will be operative to effect regulation at lower and lower intensities of the incoming waves.

The uniformity of the intermediate frequency carrier wave resulting from this method of control, corresponds to transmission through a medium of constant attenuation; the sound waves of the impressed message are reproduced with a strength that faithfully follows their original intensity regardless of the variations to which radio waves are subject in the medium.

It should be noted that the control affects only those waves that are repeated by the controlled amplifiers in the normal manner; it is not effective upon such portion of the waves that may be transmitted directly through the capacities of the amplifier electrodes.

Strong incoming waves might, under certain conditions, cause sufficient current to be transmitted through the amplified capacities to cause the control current I_c to reach and exceed the limiting value at which the amplifiers become blocked. Stronger wave intensities would then be uncontrolled, the amplifiers operating merely as fixed capacity networks to produce a fixed attenuation of the waves. By neutralizing the coupling between the input and the output circuits of the controlled amplifiers in the manner hereinbefore described, the direct transmission of the incoming wave is largely prevented and the range of intensities that can be controlled is greatly increased.

The use of two controlled amplifiers in tandem further increases the range that can be controlled by increasing the attenuation to which directly transmitted waves are subjected. Satisfactory control may, however, be obtained over a wide range of intensities using only one controlled amplifier.

An additional feature of the system described above that tends to increase the operating range of intensities, is the arrangement whereby the auxiliary wave from the local source is subjected to the action of the controlled amplifiers. As the intensity of the incoming wave increases and, through the action of the control circuit, reduces the effective amplification of the amplifiers, the strength of the auxiliary wave E. M. F. impressed upon the detector 5 is reduced.

Hence the intermediate frequency carrier approaches the limiting value at a slower rate than it would if the auxiliary wave were not controlled, and further, the component of the intermediate carrier due to the incoming wave is very small. Both of these factors are effective in extending the operating range.

With this arrangement, the demodulation of strong incoming waves in the detector takes place with a considerably weakened auxiliary wave. Such a condition may give rise to a larger number of harmonics and other undesired modulation products, but these are suppressed by the band filter 6.

An alternative arrangement of the circuit may be used in which the auxiliary wave is impressed directly upon the demodulator 5 and is therefore not subject to the action of the controlled amplifiers. To permit the use of this arrangement, a switch 28 is provided by which the local source 2 may be connected to a coupling transformer 30, the secondary of which is connected in series with the input circuit of the demodulator. With this arrangement, constant conditions in the demodulator are obtained since the incoming wave is maintained at substantially constant intensity by the control current.

The response of the control to changes in the strength of the incoming wave is exceedingly rapid; that it is not instantaneous is due only to the presence of the condensers 22 and 20 which are connected in parallel with the resistance 18. The condensers 22 are inserted to provide a low impedance connection for the high frequency waves between the cathodes and the tuning coils in the amplifier input circuits. The condenser 20 is provided to absorb the alternating current in the output of the detector 16. They are effective in reducing the rapidity of response because they require a certain small time to charge or discharge when the applied potential is changed. It is found that the total capacity may be as great as 1 mfd. without increasing the response time above one-fiftieth of a second.

In experimental tests with a system of the type described but having only one controlled amplifier, received signals have been maintained constant in strength within 10% while the impressed wave intensities varied from a minimum to a maximum value one thousand times greater.

The operation of the invention has been described in connection with a double detection system, but it is obvious that the principles involved may be applied to the control of receiving systems in which no auxiliary wave is used and which employ only one demodulation of the incoming waves. Instead of an intermediate frequency carrier wave, the carrier component of the incoming waves would be selected to

produce the control current, the selection, as in the system described, being made after the wave has passed through the controlled amplifier. The use of the double detection system, however, by establishing an intermediate carrier wave of relatively low frequency, makes it possible to separate the carrier more completely from its accompanying side frequencies and thereby to secure more exact regulation.

What is claimed is:

1. In a wave receiving system of the type in which an incoming carrier wave is demodulated with a locally generated heterodyne wave to produce a beat wave of a different frequency, a high frequency amplifier adapted to amplify both the incoming carrier wave and the heterodyne wave before demodulation, demodulating means, a rectifier adapted to produce a direct current from the beat wave, and means for controlling the efficiency of said amplifier in accordance with the strength of the rectified current whereby the intensity of the heterodyne wave applied to said demodulating means is diminished as the intensity of the incoming wave increases.

2. In a wave receiving system of the type in which an incoming carrier wave is demodulated with a locally generated heterodyne wave to produce a beat wave of a different frequency, means comprising a three electrode space discharge amplifier for amplifying both the incoming wave and the heterodyne wave before demodulation, demodulating means adapted to receive the amplified waves from said amplifier, a rectifying device for rectifying the beat waves produced by said demodulator and means for impressing the potential of the rectified current upon the control electrode of said amplifier, whereby the resistance of the space discharge path is increased in accordance with the intensity of the incoming wave.

3. In a heterodyne receiving system in which a space discharge amplifier is adapted to amplify the incoming waves and the heterodyne waves before detection, the method of controlling the sensitivity which comprises rectifying the waves of the beat frequency, and applying the rectified waves to reduce the efficiency of amplification of the incoming and the heterodyne waves.

4. In a heterodyne receiving system, a space discharge amplifier adapted to amplify the incoming waves and the heterodyne waves before detection, means for rectifying the waves of a beat frequency produced by detection and means for impressing the direct current potential of the rectified waves upon said amplifier to reduce its efficiency.

5. In a heterodyne receiving system, a method of controlling the volume of the detected signals which comprises simultaneously amplifying the incoming wave and the

heterodyne wave, and controlling the degree of amplification in an inverse manner as the amplitude of the received wave varies.

5 6. In a heterodyne receiving system, the method of controlling the volume of the detected signals which comprises amplifying the heterodyne wave prior to the step of detection, and varying the degree of amplifica-

tion in an opposite sense to and in synchronism with variations of the intensity of the 10 received wave.

In witness whereof, I hereunto subscribe my name this 28th day of November, A. D. 1924.

HARALD T. FRIIS.