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H. WEHRLIN ET AL

2,090,820

METHOD OF MODULATING HIGH FREQUENCY TRANSMITTERS

Filed June 22, 1933

3 Sheets-Sheet 1

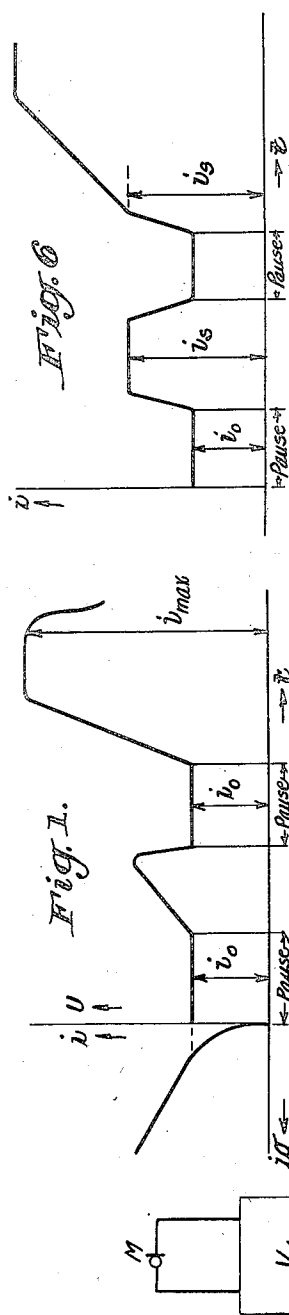
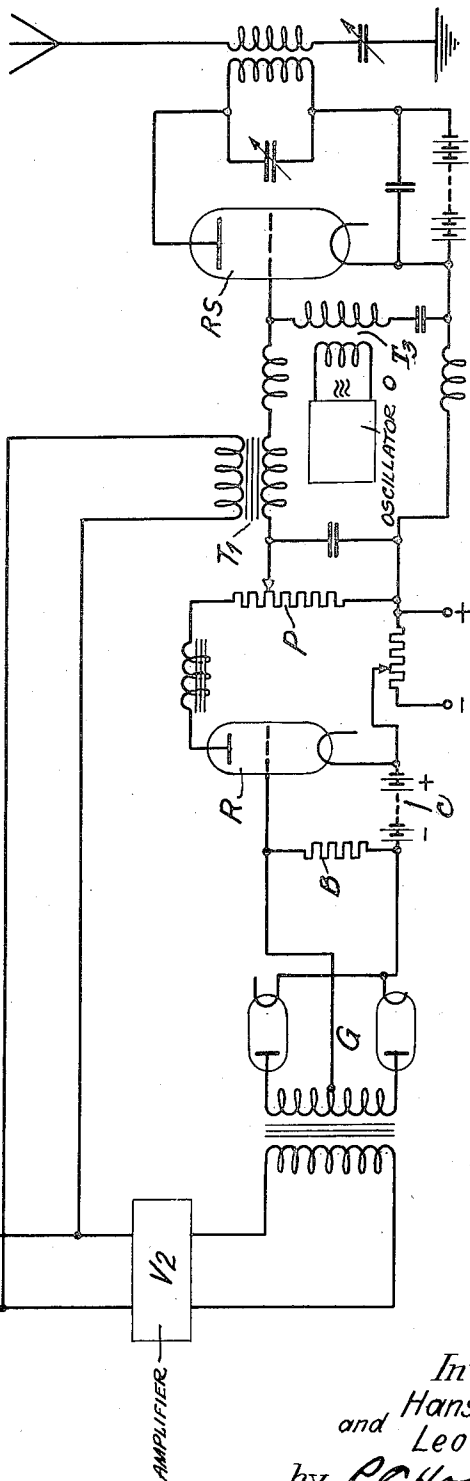


Fig. 2.

DISTORTING AMPLIFIER



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Fig.3

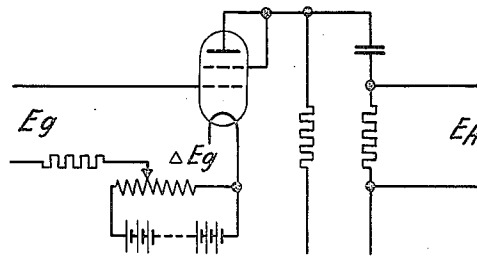


Fig.4

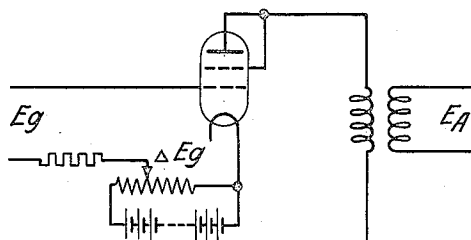
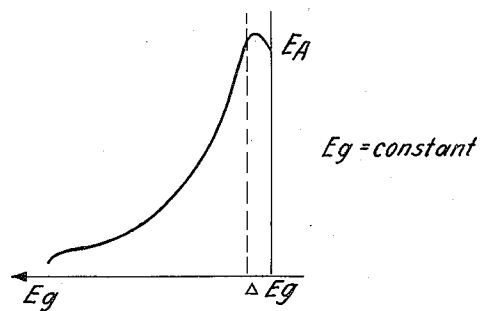


Fig.5



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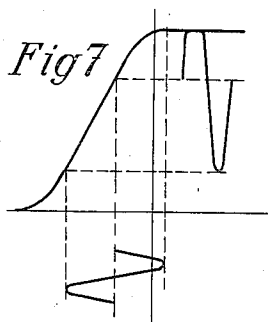
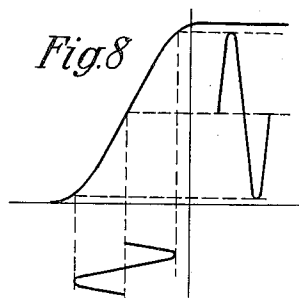
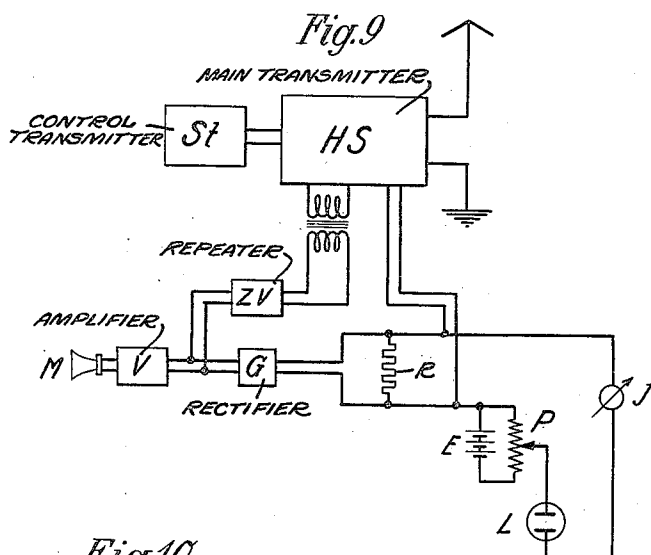
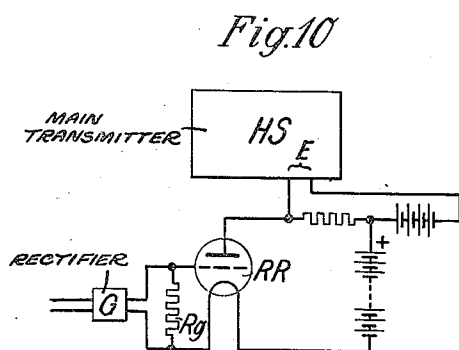
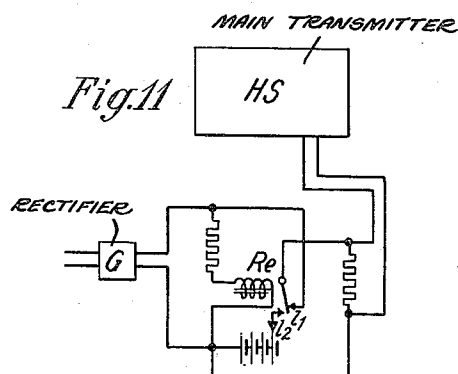
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UNITED STATES PATENT OFFICE

2,090,820

METHOD OF MODULATING HIGH-FREQUENCY TRANSMITTERS

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Application June 22, 1933, Serial No. 676,999½
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1 Claim. (Cl. 179—171)

The invention relates to a method of modulating high frequency transmitters and more particularly to a method with which the amplitude of the carrier frequency varies in dependence on the intensity of modulation.

In accordance with one object of the invention, the carrier frequency of a certain minimum amplitude, preferably corresponding to the lower end of the straight portion of the grid voltage-plate current characteristic of the modulating tube, is transmitted during non-modulation periods and when the modulation intensity is quite low, namely below a certain minimum value.

In accordance with another object of the invention, the carrier frequency transmitted does not exceed a predetermined maximum amplitude, preferably corresponding to the upper end of the said straight portion of said characteristic, so that even though the modulation intensities may exceed a certain value the amplitude of the transmitted carrier frequency is unaffected thereby.

According to another object of the invention, in a high frequency carrier wave signalling system employing a transmitter and a receiver the non-linear demodulation characteristic of the receiver is neutralized or compensated at the transmitter. The arrangement is preferably such that the amplitude of the carrier frequency is not precisely accommodated to the demodulation curve but that the displacing of the working point is limited to a certain value in downward direction and that the working point shall remain at this value even if the intensity of modulation is very small or equal to zero.

If the working point is displaced then the main saving in energy is attained by the transmitter not operating continuously with the maximum carrier current. From a certain lower value a further downward displacement of the working point does not bring about a further essential saving in energy. In general this value can be assumed to be approximately at $\frac{1}{4}$ or $\frac{1}{3}$ of its maximum value. This downward displacing should be effected to such a degree only that the receivers shall not yet be subjected to distortions.

Moreover the arrangements required for displacing the working point are simpler if, as stated before, in accordance with the invention the demodulation curve of the receiver need not be observed strictly in the lower range that requires the larger expenditure in means, but shall be so only in the upper range which is more rectilinear. In addition, the existing receivers are more or less in conformity with each other as regards the

upper part of the demodulation curve, whilst in most cases they are so to a less degree with respect to the lower part thereof.

Furthermore, the carrier current which is weak during the pauses may be used with advantage for transmitting a pause signal. If, however, no direct pause signal is sent, then nevertheless there is the advantage that the receiver is more easy to adjust to the transmitter than if the carrier frequency of the transmitter were missing entirely.

The invention will be understood from the following description and be particularly pointed out in the appended claim, reference being had to the accompanying drawings in which

Fig. 1 is a diagram illustrating the fundamental idea on which the novel method is based. Fig. 2 is a wiring diagram of an arrangement adapted for carrying out the novel method. Fig. 3 shows a circuit arrangement of an electron tube that is useful in connection with the invention. Fig. 4 represents a slight modification of the arrangement disclosed in Fig. 3. Fig. 5 illustrates the characteristic curve of tubes which are arranged as shown in Figs. 3 and 4. Fig. 6 is a diagram relating to a certain mode of modulation. Fig. 7 is a diagram relating to a known mode of transmitter operation. Fig. 8 is a diagram that relates to the mode of working of the novel transmitter. Figs. 9 to 11 each represent a circuit arrangement adapted for carrying out the invention.

In Fig. 1 there is shown as a function of the time t the evolution the carrier current undergoes on a transmission, such as a musical one, taking place. This representation in its left-hand portion also shows the mean demodulation curve. This curve represents the rectified current i_g as a function of the high-frequency voltage U . The scales for i and U being the same, this curve enables directly to read off the rectified current that corresponds to a definite antenna current. Hence also the working point for any carrier current can be ascertained. During the pauses of modulation, specially indicated in the figure, the carrier current in accordance with the invention does not approach the zero value but the value i_0 . This value corresponds to a working point that as far as possible belongs to the part where the slope of the modulation curve is approximately constant or at least essentially different from zero. From this value the carrier current increases in dependence on the modulation intensity, in order then to decrease to the value i_0 during the pauses of modulation and with small values of modula-

tion. In the example represented the minimum value i_0 is about $\frac{1}{3}$ of the maximum value i_{max} .

The arrangement shown in Fig. 2 is for the case of modulation of grid potential with a separately excited transmitter. M denotes the microphone, V_1 the modulation amplifier from which the normal modulation voltage acts on the transmitter over the transformer T_1 . Over a second amplifier V_2 and the rectifier G the continuous voltage for displacing the working point arrives. The distortion for the accommodation to the demodulation curve of the receiver may here be effected either in the amplifier V_1 or in amplifier V_2 . In one case only the modulation curve is distorted, whilst in the other case the displacing of the working point too is influenced by the distortion. For producing this compensating distortion at the transmitter an electron tube of the variable μ type is preferably employed. The special construction of the grid of such a tube causes a gradual change in the mutual conductance or transconductance of the tube near the lower portion of the plate current-grid voltage characteristic curve. Different degrees of amplification are then obtained in accordance with the different grid biases. These tubes above all have the advantage that they are controlled almost without power input, since the working points lie in the range of negative grid bias.

Figs. 3 and 4 relate to the working with tubes of this kind, Fig. 3 shows a capacity-resistance coupling, Fig. 4 a transformer coupling. Should the tube also contain a screen or protective grid, it is advantageous to connect said grid to the anode since, due to the low frequencies at which the tube is operating, a more favorable relationship is thereby obtained between the internal resistance of the tube and the impedance of the output circuit.

Since, as shown in Fig. 5, the characteristic of such tubes has a maximum due to the overmodulation effected with small negative grid potential, it is advantageous to provide for a constant bias ΔE_g in addition to the variable control voltage, in order always to work on that part of the characteristic curve which is situated on the left-hand side with respect to this bias.

The undistorted modulation currents of the microphone M (Fig. 2) are conducted to the input E_g of the arrangement represented in Fig. 3 or Fig. 4, while from the output E_a the correspondingly distorted modulation voltages are derived.

In the arrangement shown in Fig. 2 the minimum value of the carrier current is in accordance with the invention regulated by means of the potentiometer P. The potentiometer P is the means by which the grid of the tube RS is biased. When the swing of the grid excitation voltage applied through the transformer T_3 from the source of continuous oscillations O is greater than that required to reduce the plate current to a value below the straight portion of the plate current-grid voltage characteristic, the grid biasing potential is the controlling factor in the alternating or carrier current output of the tube. The biasing potential is regulated so that with zero or low modulating voltages there is at least a minimum value i_0 of antenna carrier current. On any increase in intensity of the modulating voltage above the amount required to produce the minimum carrier current, there is a decrease in the bias of the tube RS thereby permitting an increase in the carrier current transmitted. To illustrate—if there is no modulating voltage ap-

plied to the full wave rectifier G the biasing voltage applied to tube R is only that due to the battery C and this bias is of such value that the plate current of tube R, flowing through the resistance of potentiometer P, produces the necessary voltage drop properly to bias the tube RS. If a modulating voltage is next applied to the rectifier G, the rectified current flowing through the resistance B produces a voltage drop which, when added to the voltage of the battery C, causes the grid of tube R to become more negative. This, in turn, reduces the plate current of tube R and thereby causes a decrease in the negative voltage across potentiometer P. This decrease across potentiometer P causes an increase in the antenna carrier current, as previously explained.

According to the invention, the biasing voltage of tube RS may be so shown that the minimum value of antenna current i_0 falls below the straight line portion of the characteristic curve. Assuming such a case, the circuit may be so adjusted that on modulation taking place the resulting change in bias on tube RS is in such a direction and of such value as to increase the minimum carrier current to the value i_0 (Fig. 6) which is the value at which the plate current-grid voltage characteristic begins to be rectilinear. Any further increase in modulation intensity causes the carrier current to vary along the rectilinear portion of the characteristic curve, in accordance with the modulation intensity.

In some cases it is advantageous to limit the displacing of the working point not only downward but also in upward direction. By so doing the undesirable effects of overmodulation can be obviated. For in the event of such modulation peaks the working point rises beyond the normal half-value and hereby the unpleasant incidents due to overmodulation are still increased.

In Figs. 7 and 8 there are represented in a quite diagrammatic manner the conditions of a transmitter without limitation of the working point (Fig. 7) and with a limitation of this nature (Fig. 8) as set forth by the invention. The transmitter operating in accordance with Fig. 7 proves to be much overmodulated, whilst the transmitter constructed according to Fig. 8, i. e. according to the invention shows a uniform modulation curve. The limitation of the working point can here be effected by all devices that operate with any bent or saturated voltage characteristic.

With the arrangement represented in Fig. 9, in the input circuit of an amplifier V a microphone M is included the amplified currents of which are on the one hand conducted to a rectifier G and on the other hand led to an intermediate repeater ZV. The rectifier G as well as the intermediate repeater ZV act upon a main transmitter HS influenced by a control transmitter St. Disposed in the output circuit of the rectifier G is a resistance R to which a glow discharge lamp L is connected in parallel. A potentiometer P, connected in advance of the lamp L, and the auxiliary potential supply E permit of adjusting the ignition voltage of the lamp L to a desired value. Whenever the modulation exceeds a certain value and a certain voltage at resistance R is exceeded thereby, the lamp L is ignited and thereby acts to limit the voltage so that this cannot rise beyond a certain value. The adjusting is here made so that the limitation occurs on the half-value becoming attained. The measuring instrument J included in the circuit of lamp L may serve for supervising the over-

modulation. The lamp L may serve the same purpose. When it is lit this indicates that the transmitter is fully modulated. If the ignition voltages used are low, a thermionic gas discharge tube may be employed instead of the glow discharge tube.

The circuit arrangement shown in Fig. 10 differs from that before described in this that a tube R'R having a curved characteristic is employed. In the grid circuit of this tube a resistance R_g is disposed so that on the modulation increasing an increasing grid bias is conducted to the tube. The bend of the tube characteristic acts to limit the work of the tension E derived from the anode side, this tension in its turn influencing the grid bias of the transmitter.

The arrangement illustrated in Fig. 11 operates with a relay R_e , that responds whenever a certain voltage is exceeded. On the relay responding the contact I_1 is opened and a constant grid bias is supplied over contact I_2 as long as the modulation amplitudes which correspond to the half-value continue to be exceeded.

The arrangements represented in Figs. 9 to 11 may be employed immediately with the arrangement shown in Fig. 2, for influencing the grid bias of the transmitting tube RS.

What is claimed is:

In a carrier wave signalling system employing

a transmitter for transmitting a modulated wave derived from a signal and a carrier, and a receiver having non-linear demodulation characteristics for demodulating said wave to reproduce said signal, the method of deriving from said signal and said carrier the modulated wave to be transmitted which comprises distorting the signal amplitude to compensate for the non-linear demodulation characteristics of the receiver, varying the mean carrier intensity in accordance with the mean signal intensity, limiting said varying of said carrier intensity in such manner that this mean intensity does not fall below a fixed positive value during intervals when the mean signal intensity is zero, further limiting said varying of said carrier intensity so that said intensity remains at a fixed upper value during intervals when the mean signal intensity is above a predetermined maximum value, and modulating the carrier so controlled in conformity with the instantaneous amplitudes of the distorted signal so that the instantaneous intensities of said carrier are determined by the instantaneous amplitudes of said distorted signal while the mean intensity of said carrier depends upon the mean controlled intensity of said carrier before modulation.

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