Feb. 4, 1930. E. I. GREEN 1,745,415

CARRIER AMPLITUDE CONTROL SYSTEM

Filed Oct. 29, 1926

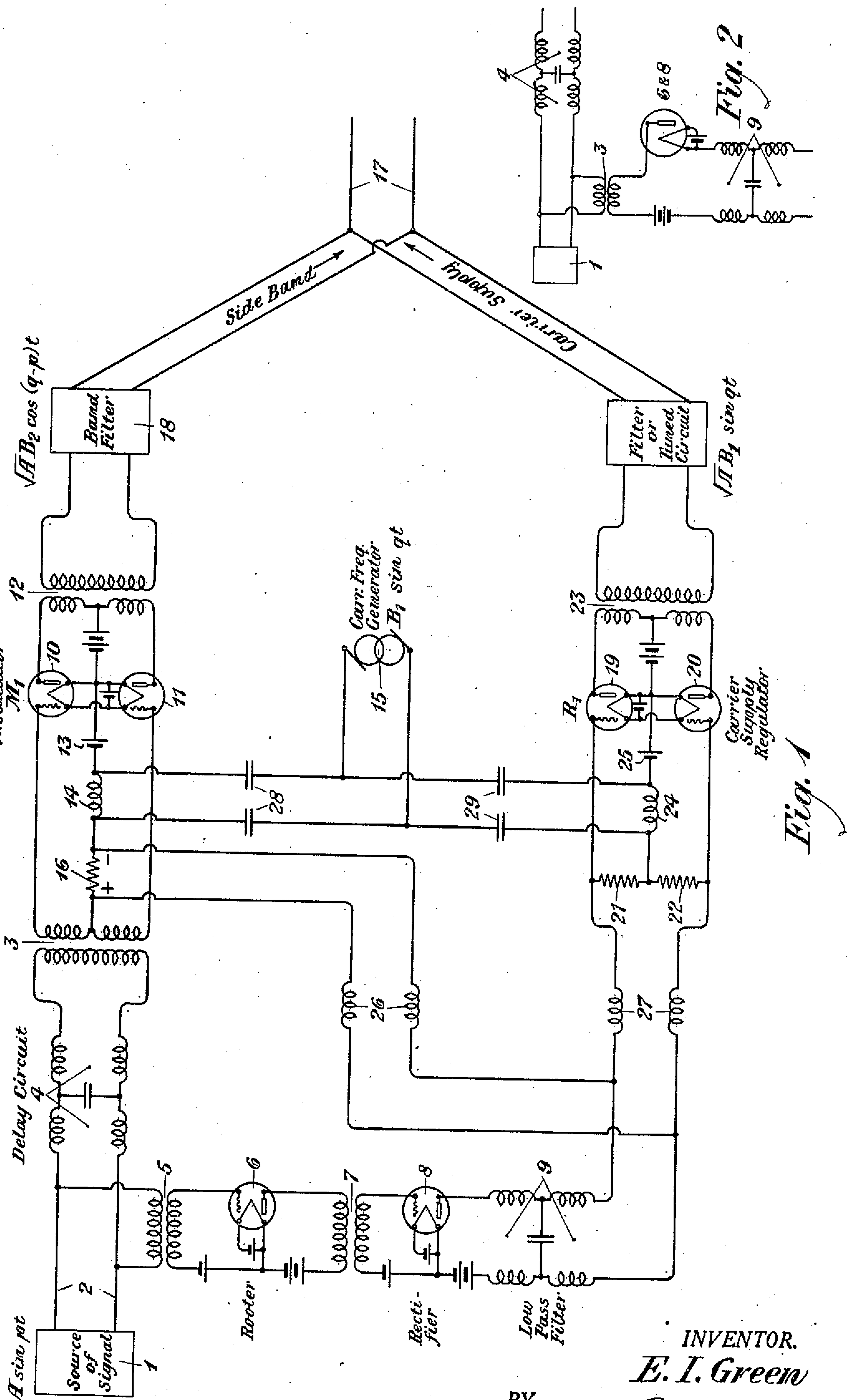

Fig. 1

Fig. 2

INVENTOR.
E. I. Green
BY
ATTORNEYS.

Patented Feb. 4, 1930 **1,745,415**

UNITED STATES PATENT OFFICE

ESTILL I. GREEN, OF EAST ORANGE, NEW JERSEY, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK

CARRIER AMPLITUDE CONTROL SYSTEM

Application filed October 29, 1926. Serial No. 145,050.

This invention relates to a carrier or radio system characterized by the simultaneous transmission of the carrier frequency and one or both of the side bands produced by the modulation of the carrier by a signal frequency, and particularly to a method and means for maintaining constant the ratio of the amplitude of the side band to the amplitude of the transmitted carrier.

In the method heretofore employed in radio transmission or broadcasting, and also in carrier systems in which the carrier frequency is simultaneously transmitted with one or both of the side bands resulting from modulation of the carrier by a frequency or band of frequencies representing the load to be transmitted by the carrier, the amplitude of the carrier frequency per se remains substantially constant, whereas the amplitude of the side bands increases and decreases in accordance with the instantaneous values of the frequency or frequencies employed in modulating the carrier. For example, during the transmission of speech, music, or other sound over a carrier system, there will be times when the side bands will cease to exist, which times correspond to a pause in the signal being impressed upon the transmitter of the system. In such intervals, the carrier frequency continues to flow over the system to the detector at the receiving station. Any extraneous interference or noise lying within the frequencies of the side band will be demodulated with this carrier by the detector at the receiving station. The objection to this situation is that during these pauses the receiving system is as responsive to noise conditions on the circuit as it is when the signal band is being received.

In the Patent No. 1,681,972, that issued to Blackwell and Affel, on August 28, 1928, is disclosed a method for controlling the amplitude of the carrier in accordance with the changes in the amplitude of the signal by which the carrier is modulated, the system being characterized by a side band of variable amplitude and a carrier of constant amplitude.

My invention is a modification of that disclosed in said Blackwell and Affel patent, the modification consisting in a method and means for maintaining constant the ratio of the amplitude of the envelope of the transmitted side band to the amplitude of the envelope of the transmitted carrier.

In the arrangement of Messrs. Blackwell and Affel, it is proposed to reduce the noise during the periods when there is little or no signal input by reducing the amount of carrier transmitted at such times. Thus, the arrangement provided for the variation of the envelope of the transmitted carrier in accordance with the variation in the envelope of the signal input wave. In such a system, the reduction of the noise during periods of light load or no load is accomplished at the expense of an increase in the transmitted power and received noise during the louder portions of the signal. In the present invention, the variations in the envelope of the signal wave are equally divided between the transmitted carrier and the transmitted side band, with the result that the noise during periods of light signal load or no load is kept a minimum, while the transmitted power and received noise during periods of heavy load are likewise kept a minimum.

This invention will be clearly understood from the following description when read in connection with the attached drawing of which Figure 1 shows schematically a form of the invention, and Fig. 2 shows a variation of a portion of the circuit shown in Fig. 1.

In the drawing a source of signal 1 is connected with the input circuit 2. This source is capable of producing a signal which, for purposes of discussion, may be represented by A sin *pt*. The circuit 2 is connected with the primary winding of the transformer 3, the connection including a delay circuit 4, the function of which is to interpose a time lag in the application of the voltage produced by the source 1 upon the modulator M_1. The circuit 2 is also connected with the primary winding of the transformer 5. The secondary of this transformer is connected with the input circuit of the vacuum tube 6, the output side of which is connected with the primary of the transformer 7. The circuit of the vacuum tube 6 is so adjusted that the current flowing through its output winding is proportional to the square root of the current flowing through the primary winding of the transformer 5. The secondary of the transformer 7 is connected with the input circuit of the rectifier 8, the output circuit of which is connected with the modulator M_1 and the carrier supply regulator R_1. The output circuit of tube 8 contains a low pass filter 9, the function of which is to suppress all currents except those of very low frequency, the cut-off value of the filter being slightly above the frequency corresponding to the changes in the envelope of the input signal wave.

The modulator M_1 is of the well known balanced type comprising the tubes 10 and 11, which are symmetrically connected with the secondary winding of the transformer 3 and the primary winding of the transformer 12. The conductor that is common to the grids of both tubes contains a negative biasing battery 13, an inductance 14 across which the carrier voltage from the source 15 is impressed, and a resistance 16 across which the rectified voltage from the tube 8 is impressed. The secondary winding of the transformer 12 is connected with the transmission circuit 17, the connection including the band filter 18 which is adapted to suppress the unwanted products of modulation. It may be arranged to transmit both of the side bands resulting from the modulation, although in this case, it is assumed to suppress one of the side bands of modulation and to transmit the other, as, for example, that represented by $\sqrt{A}B_2 \cos (q-p)\, t$, where A is the variable coefficient of the signal input, and B_2 is constant.

The carrier frequency generator may be of any well known type, such, for example, as the vacuum tube oscillator. This generator produces a carrier wave which may be represented by $B_1 \sin qt$. The regulator R_1 consists of a balanced tube structure, comprising tubes 19 and 20 which are symmetrically connected with the equal resistances 21 and 22 and also with the primary winding of the transformer 23. The carrier oscillator 15 is connected across the inductance 24 in the common conductor of the grid circuits of the tubes 19 and 20, which conductor also contains the biasing battery 25. The function of this regulator is to control the amplitude of the carrier that is sent over the line 17 simultaneously with the side band transmitted by the filter 18. Since the regulator is a balanced tube structure in which the carrier frequency is applied to the common conductor, the carrier will not be transmitted so long as the circuit is electrically balanced. Whenever a rectified voltage is impressed across the resistances 21 and 22 in series as the result of the rectification of the signal, the balance will be disturbed and a carrier voltage will be applied across the line 17, the amplitude of which is dependent upon the rectified voltage applied to the resistances 21 and 22. The choke coils 26 and 27 serve to prevent a transfer of high frequency currents over the circuits in which the choke coils have been placed, and the condensers 28 and 29 serve to prevent direct currents flowing over the circuits in which they are placed.

The manner in which this circuit functions in order to attain the desired result, namely, a constant ratio between the amplitude of the side band and that of the carrier, is as follows: The signal voltage $A \sin pt$, produced by the source 1, will be impressed across the primary windings of the transformers 3 and 5, but due to the presence of the delay circuit 4 the time of application of the voltage to the winding of 3 will be somewhat later than its application to the winding of 5. This delay is interposed in order that the signal voltage may be set up across the winding of the transformer 3 at approximately the same instant that the rectified voltage resulting from the transmission of the signal around the path comprising 5, 6, 7, 8, 9, and 26, is applied to the resistance 16.

The voltage $A \sin pt$ impressed across the input side of the device 6 will produce a voltage across the input side of the rectifier 8 that is proportional to the square root of the amplitude of the wave $A \sin pt$. The rectified voltage will be proportional to the envelope of this wave, that is, the rectified voltage is proportional to the square root of A. This rectified voltage will of course vary from time to time, depending upon changes in the amplitude of the envelope of the signal wave. The rectified voltage will be impressed across the resistance 16 in the input circuit of the modulator M_1 and will also be impressed across the resistances 21 and 22 in the input circuit of the regulator R_1. The amplitude of the carrier supplied by the source 15 to the modulator M_1, will be constant. This carrier will be modulated by the signal that is impressed across the secondary of the transformer 3. The amplitude of the side bands produced by the modulator M_1 would normally be proportional to the signal input, but in this case it will be controlled in an inverse manner by the voltage impressed across the resistance 16, and this amplitude will therefore be directly proportional to the square root of the envelope of the signal, that is to say, the side band amplitude will be proportional to the square root of A. The modulating carrier will be balanced out, while one of the side bands, for example, that represented by $\sqrt{A}B_2 \cos (q-p)t$, will be selected by the filter 18, and transmitted over the line 17. At the same time the rectified voltage impressed across the resistances 21 and 22 will unbalance the regulator and permit the transfer to the line 17 of a carrier represented by $\sqrt{A}B_1 \sin qt$, where A has the same significance as before, and B_1 is constant. The side band

and carrier will be received by suitable apparatus connected with the line 17, and the demodulated product of the carrier and side band will of course contain the first power of A so that it will be a true reproduction of the original signal input applied at 1. It will of course be noted that with this system we have a constant ratio of the carrier to the side band, namely, $\frac{B_1}{B_2}$, and that the variations in the envelope of the original signal wave are divided uniformly between the transmitted carrier and the transmitted side band.

For satisfactory transmission over a carrier system it is necessary that the variations in the output of the receiving demodulator be the same as the variations in the signal input. There are numerous ways in which the transmitted carrier and side band may be related while still satisfying this condition, but three relations are of special interest for purposes of analysis.

First, there is the ordinary type of transmission in which the carrier is constant while the side band envelope varies in accordance with envelope of the signal input. Using the same general notation as before, this system may be considered as transmitting to the line a carrier $B_1 \sin qt$ and a side band $AB_2 \cos (q-p)t$, where A varies according to the volume of the signal input, and B_1 and B_2 are constants.

Secondly, there is a type of transmission precisely opposite to the above, namely, that in which there is transmitted to the line a constant side band accompanied by a variable carrier supply. For this method the side band may be designated $B_2 \cos (q-p)t$, and the carrier as $AB_1 \sin qt$.

Thirdly, there is the method of the present invention, which transmits to the line a side band equal to $\sqrt{A}B_2 \cos (q-p)t$, and a carrier equal to $\sqrt{A}B_1 \sin qt$.

It is clear that for each of these three methods the demodulator output will contain the first power of A, and satisfactory transmission will be obtained. There are, however, very important differences between the three with respect to the amount of noise obtained at the receiver and the amount of transmitting power required. The reason for these differences lies in the well known fact that for satisfactory quality the magnitude of the received carrier must always be greater than that of the received side band.

If, now, in the ordinary system having a constant carrier and a variable side band, the ratio of carrier to side band is made correct for the maximum signal input there will be an excess of carrier, and consequently, an excess of noise, whenever the magnitude of the signal input is below the maximum value.

Furthermore, if in the system having a variable carrier and a constant side band, the magnitude of the carrier is made correct for the minimum signal input there will be a great excess of carrier for the larger magnitudes of signal input, and this excess involves both an increase of noise during the loud periods and an increase in the transmitted power required at such times. The latter is, of course, objectionable in that it requires a greatly increased carrying capacity in the transmitting apparatus.

In the arrangement of the present invention, however, the ratio of carrier to side band is kept always at the minimum value permissible for good quality, and as a result, the minimum amount of noise is obtained under all conditons of signal load, as well as the minimum amount carrying capacity in the transmitting apparatus.

It is obvious that many variations may be introduced in the circuit arrangement of Fig. 1 without departing from the spirit of this invention. Thus, the modifying characteristic of the tube 6 may be combined with the rectifying action of the tube 8 so that both functions are performed in a single tube. Such a modification of that portion of the circuit is shown in Fig. 2, in which the transformer 5 is shown connected directly to a rectifier tube marked 6 and 8, this tube having the proper characteristic to perform both functions.

Likewise, although the invention has been described as applied to a system in which only one of the side bands of modulation is transmitted, it may evidently be used in a system in which both side bands are transmitted, in which case, the envelopes of both side bands will be controlled in accordance with the square root of the envelope of the signal input.

Other methods of carrying out this invention which differ in their particular form and arrangement of parts from the arrangements which have been described, will be readily apparent, and it is to be understood that these modifications still come within the spirit and scope of the appended claims.

What is claimed is:

1. In a signaling system in which a carrier frequency is modulated by a signal current, the method which consists in varying the envelope of the transmitted carrier in accordance with the square root of the envelope of the signal current, and simultaneously varying the envelope of the transmitted side band current in accordance with the square root of the envelope of the signal current.

2. In a signaling system in which a carrier frequency is modulated by a signal current, the method which consists in distributing the variations in the envelope of the signal current equally between the transmitted carrier and the transmitted side band frequencies.

3. In a signaling system, a source of tele-

phone current wave of varying volume, a source of carrier frequency, means for producing from said telephone current wave and said carrier frequency a side band wave whose envelope varies in accordance with the square root of said telephone current wave, means for producing a carrier wave whose envelope varies in accordance with the square root of said telephone current wave, and means for transmitting said variable carrier wave in conjunction with said side band wave.

4. In a signaling system, a source of telephone current wave of varying volume, a source of carrier frequency, means for modulating said carrier frequency with said telephone current wave, means for transmitting a side band wave produced by said modulating means, means for transmitting a carrier wave of varying magnitude, and means for making constant the ratio of the envelope of the transmitted carrier to the envelope of the transmitted side band.

5. In a carrier or radio signaling system in which a carrier frequency and a side band are transmitted, the method which consists in maintaining constant the ratio of the envelope of the side band to the envelope of the carrier throughout the system.

6. In a signaling system, the combination with a source of a telephone current wave of varying volume, of a source of a carrier frequency wave, means for modulating the said carrier frequency wave by the said telephone current wave, means for securing in the said modulating means a degree of amplification that is inversely proportional to the square root of the amplitude of the envelope of the said telephone current wave, means for transmitting a part of the output of the said modulating means, means for varying the magnitude of the said carrier frequency in accordance with the square root of the amplitude of the envelope of the said telephone current wave, and means for transmitting the carrier frequency wave as thus varied in magnitude.

In testimony whereof, I have signed my name to this specificaton this 27th day of October, 1926.

ESTILL I. GREEN.