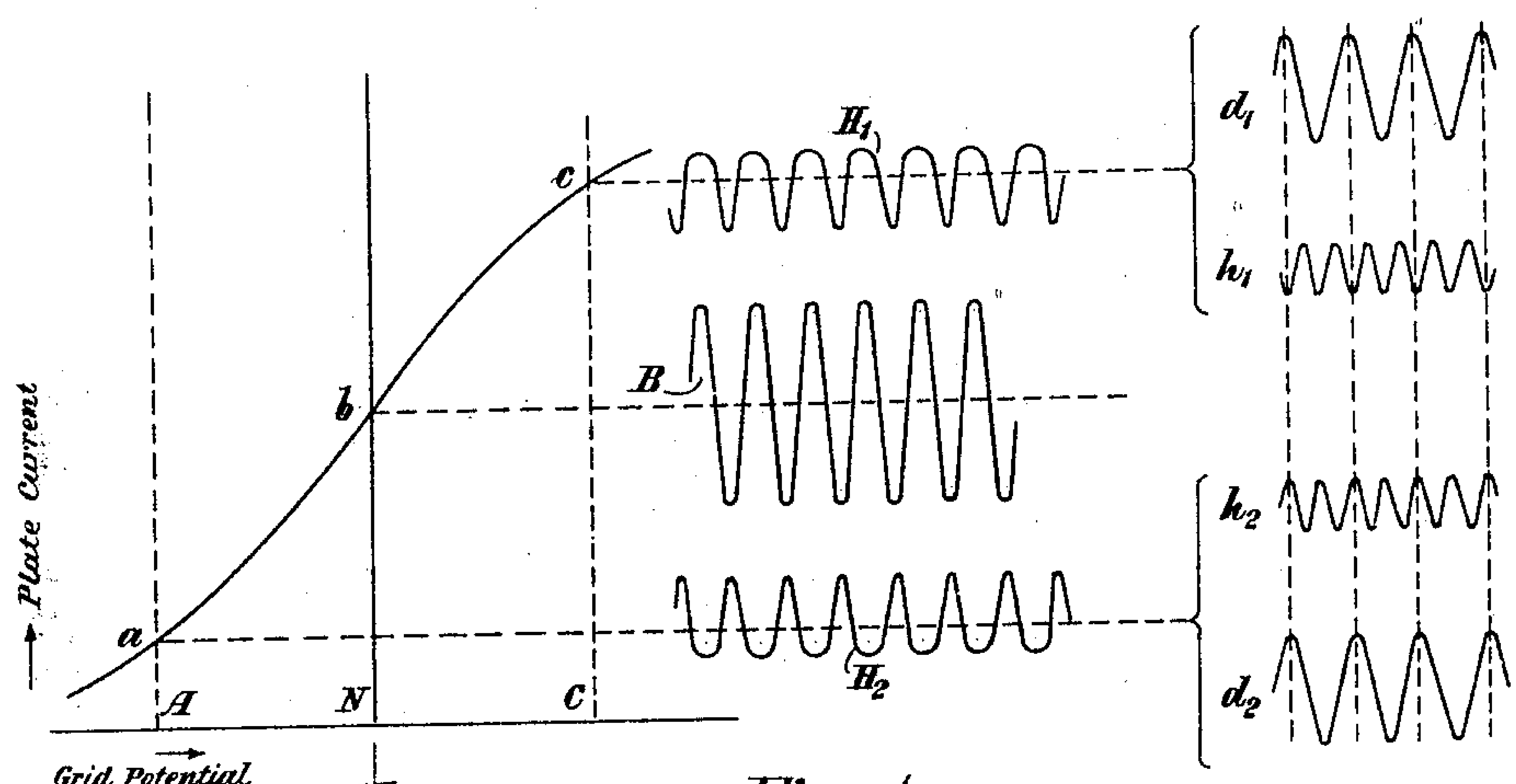
Jan. 22, 1929.

1,699,570

R. K. POTTER

CARRIER SUPPRESSION MODULATION

Filed Sept. 23, 1927



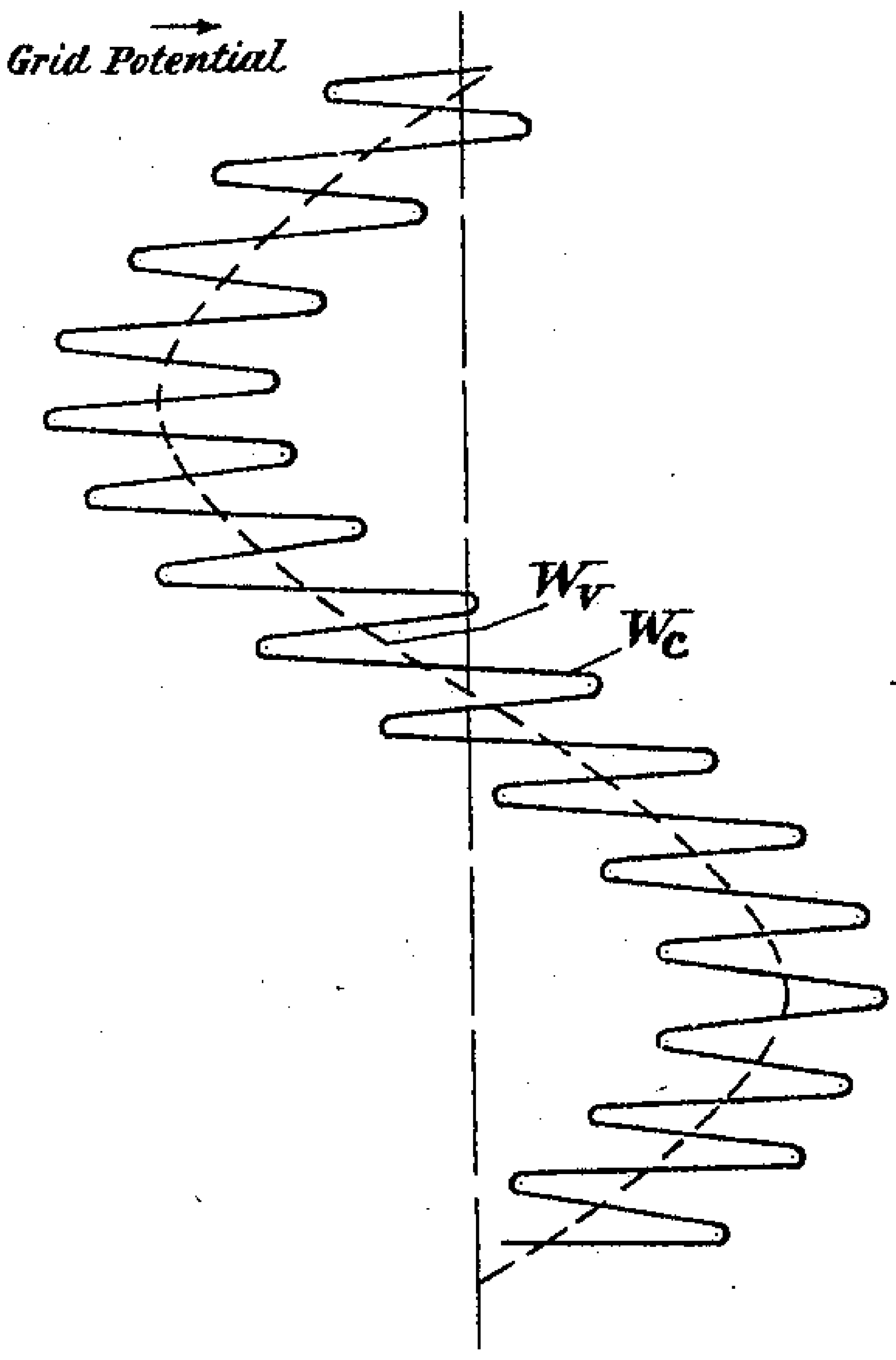


Fig. 1

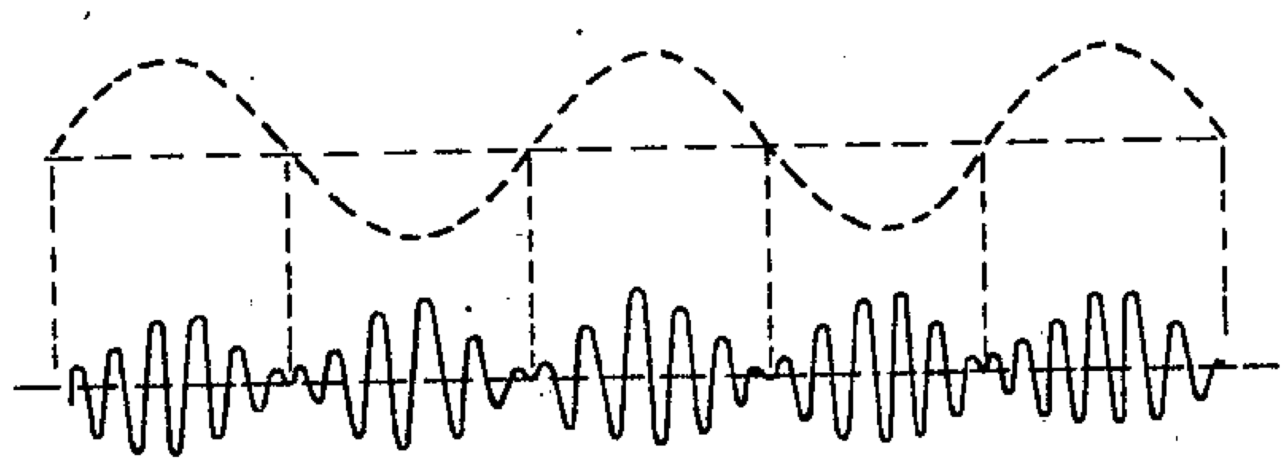


Fig. 2

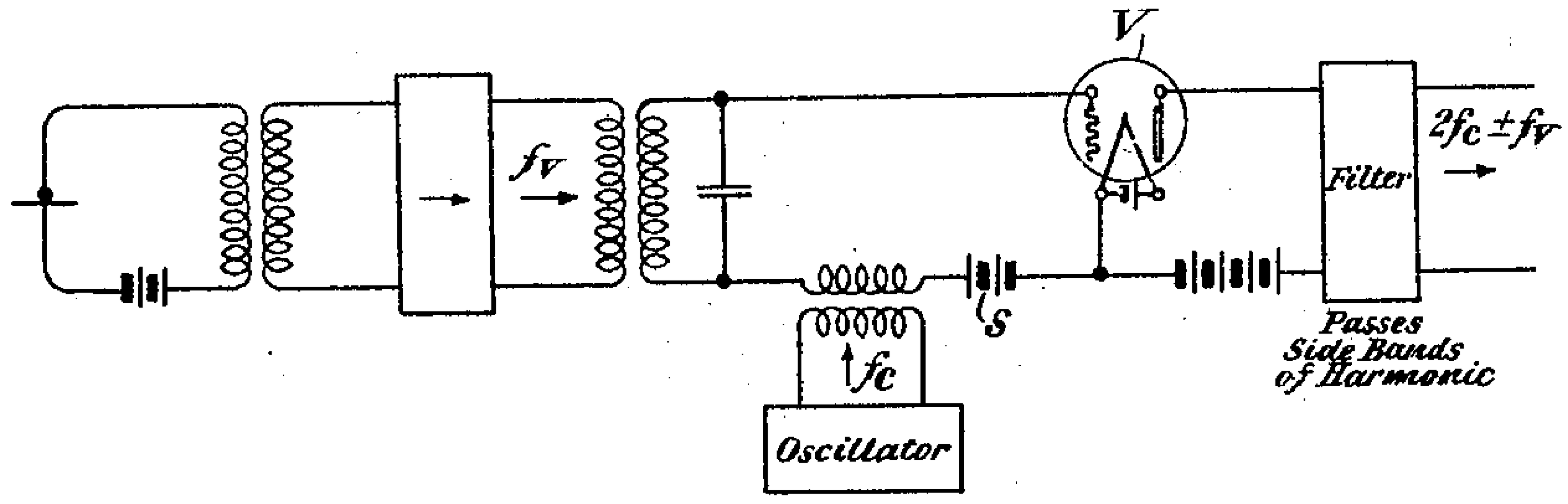


Fig. 3

INVENTOR.
R.K. Potter

BY

[signature]
ATTORNEY

Patented Jan. 22, 1929. 1,699,570

UNITED STATES PATENT OFFICE.

RALPH K. POTTER, OF NEW YORK, N. Y., ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

CARRIER SUPPRESSION MODULATION.

Application filed September 23, 1927. Serial No. 221,554.

This invention relates to translating systems, and more particularly to modulator arrangements, and is applicable, for instance, to signal transmitting systems—more particularly, radio transmitting systems—in which it is often desirable to modulate between carrier currents and the signaling currents to produce in the output of the translating device side-bands, which side-bands (or one of them) may be selected and transmitted to the distant station, the carrier frequency component being suppressed.

The principal object of the applicant's invention is to modulate, and to suppress the carrier, by a method which is simpler than any heretofore employed.

In general, the applicant uses a single translating device having certain characteristics and so adjusts the device that it will function as a carrier suppression modulator, without the requirement of outside balancing means, modulated harmonic products of the impressed radio frequency wave being selected in the output of the device instead of the side-band products of the fundamental radio frequency wave.

The principal advantage of the applicant's method is that it permits the accomplishment of carrier suppression modulation in a single translating device. A further advantage is that with the use of the novel method, the modulator may function also as a frequency multiplier, this frequency multiplication being desirable in certain types of radio transmission systems, particularly in connection with the use of the shorter wave lengths.

These and other advantages of the invention will appear more clearly in the following detailed description.

The description of the invention is to be read with reference to the accompanying drawing. Figure 1 of the drawing shows diagrammatically the characteristic of the translating device employed, and indicates the input energy applied to the device and the waves in the output circuit resulting from variation of the input energy. Fig. 2 shows diagrammatically the form of the voice wave in the input and the resultant output of a translating system used for the practice of the applicant's method and the interrelation of the voice input and the output. Fig. 3 shows diagrammatically the single vacuum tube system which may be used for the practice of the invention.

As indicated above, the applicant proposes to use the modulation of the voice currents with a harmonic of the "carrier" wave instead of the modulation of the voice with the fundamental "carrier" wave. The translating device employed may be any such device which has a non-linear but symmetrical characteristic. The device which is perhaps the most desirable for use in the practice of the method is a three-element vacuum tube having the characteristic described above. The characteristic of such a tube is shown in Fig. 1 as $a\ b\ c$, the grid potential being plotted against plate current in the diagram. If the grid biasing voltage is brought to the point N which corresponds with the symmetrical mean of the tube characteristic at b, and if the radio frequency represented by the wave W_c is impressed on the input of the tube, there will be no even harmonics of the radio frequency—or practically none—in the tube output. This may be shown mathematically as follows:

A curve which is symmetrical about a point (as is the vacuum tube characteristic shown in Fig. 1) may be represented mathematically by a series of odd powers as,

$$f(x)=ax+bx^3+cx^5+dx^7+\ \ldots\ldots \qquad (1)$$

Assuming the wave W_c to be impressed upon this tube to vary according to the relation,

$$W_c=A \sin pt, \qquad (2)$$

and substituting W_c for x in equation (1) we have,

$$f(x)=a(A \sin pt)+b(A \sin pt)^3+c(A \sin pt)^5+\ \ldots\ldots \qquad (3)$$

The expansion of this expression gives,

$$f(x) = aA \sin pt + \frac{3bA^2}{4} \sin pt - \frac{bA^3}{4} \sin 3\ pt + \frac{cA^5}{16} \sin 5\ pt - \frac{5cA^5}{16} \sin pt + \frac{15cA^5}{16} \sin pt - \frac{5cA^5}{16} \sin 3\ pt + \ldots \quad (4)$$

Equation (4) contains only the odd multiples of the fundamental frequency of the wave W_c, so that the second harmonic—in fact any of the even harmonics is not present in the tube output.

With such adjustment of the grid biasing voltage, the output of the tube may be represented by wave B which, it is assumed, contains none of the selected harmonic to which the output circuit is to be tuned.

If, now, a low frequency voice wave W_v is applied to the input, the mean grid potential will be changed from the normal at N to the more positive position C and the less positive position A, alternately. With this variation of the mean grid voltage, distortion occurs and the unsymmetrically distorted waves H_1 and H_2 will appear in the output. If these waves H_1 and H_2 are analyzed, it will be found that the components are h_1 and d_1, and h_2 and d_2, respectively. In the case of wave H_1, d_1 represents the fundamental component and h_1 the second harmonic component. Likewise, in the case of wave H_2, d_2 and h_2 represent the fundamental and second harmonic components, respectively. It will be understood, of course, that the wave form in the output varies from B to H_1 and from B to H_2 as the mean grid voltage increases or decreases from the normal. From the above analysis of the waves H_1 and H_2, it appears that although the fundamental frequency content of these waves suffers no reversal of phase as the grid bias is changed from A to C and from C to A, the even harmonics of the fundamental carrier frequency undergo a reversal in phase of 180 degrees. It will be noted further that the amplitudes of these waves pass through zero at the symmetrical mean of the characteristic *a b c*. From the above discussion, it will be understood that if a single three-electrode vacuum tube is employed and if the grid voltage is adjusted as described above, the second harmonic of the improved radio frequency being selected, the resultant output of the translating device will be represented by a wave in some such form as the lower wave of Fig. 2, the upper wave of this figure representing the modulating voice wave. Here, it will be noted that the amplitude of the modulated wave passes through zero when the amplitude of the modulating wave is zero. Also, as will be noted, at the point at which the modulated wave passes through zero, it undergoes a phase reversal. These conditions will be recognized as conditions characteristic of a carrier suppression modulator output.

In Fig. 3 of the drawing there is shown diagrammatically the apparatus which will function in accordance with the applicant's invention as a single tube carrier suppression harmonic modulator. The arrangement differs from that of a simple grid modulating system only in that the grid of the tube V is biased so that its mean potential corresponds to the symmetrical mean of the tube characteristic for the particular harmonic selected, this being accomplished by adjustment of the battery S, and in that a filter is placed in the output circuit which passes only the side-bands of the selected harmonic. Let it be assumed that the harmonic selected is the second. From the oscillator a carrier frequency f_c is impressed on the input of the translating circuit. Also the voice frequency f_v is impressed thereon. The output of the filter in the plate circuit of the tube V will then, in accordance with the method described above, be $2f_c$ plus or minus f_v. The "carrier" f_c is modulated with the voice f_v, and what is passed is the side-bands of the second harmonic of the "carrier" frequency f_c. If, for example, in equation (1) we substitute for x,

$$x = (A \sin pt + B \cos wt) \quad (5)$$

where A sin pt represents the high frequency wave W_c, and B cos wt represents the audio frequency wave, there results a series of terms which may be tabulated as follows:

$$(A \sin pt)^{2n+1} \quad (6')$$
$$(A \sin pt)^{2n} (B \cos wt) \quad (6'')$$
$$(A \sin pt)^{2n-1} (B \cos wt)^2 \quad (6''')$$
$$(A \sin pt)^{2n-2} (B \cos wt)^3 \quad (6'''')$$
etc.

The term (6′) will not pass the filters in the tube output. The term (6″) contains the modulation components of the fundamental audio frequency wave and harmonics of the wave W_c. One of these modulation components representing the side-bands of a modulated harmonic is selected by means of a filter in the modulator tube output, as shown in Fig. 3. The terms (6‴), (6⁗), etc., contain modulation components which do not pass the output filter, and a small amount of distortional component of the transmitted side-band frequency. The distortional component is, however, small compared to the amplitude of the undistorted side-band as in any of the well known modulation circuits. In the mathematical discussion of ordinary modulation circuits these terms are usually treated as "negligible" and disregarded.

The distinction between the applicant's single tube carrier suppression modulator and the duplex carrier suppression modulator, now well known in the art, is to be understood. In the duplex device, the carrier is the fundamental high frequency impressed on the input circuits, and this carrier is actually present in both sides of the duplex circuit output. The output circuit, however, is so arranged that the carrier component in one side is neutralized by the carrier component in the other side, in the associated circuit which carries the resultant output of the system. What is selected is the side-bands of the fundamental high frequency impressed on the input.

In the applicant's arrangement, on the other hand, it is not the modulation between the low frequency and the fundamental high frequency impressed on the input which is used, but the modulation between the low frequency and one even harmonic of the fundamental high frequency. The carrier is not the fundamental but an even harmonic; and, with the tube adjusted as described above, this harmonic carrier does not—at least in practical amount—appear at all in the system. It is suppressed by the neutralization due to the action of the tube; since it does not appear in the output, there is no need to balance it out. What is selected in the output is the side-bands of an even harmonic of the fundamental impressed high frequency—which harmonic "component" is suppressed (or non-existent, so far as appearance in the circuits is considered).

It is to be understood that the above detailed description serves the purpose of clear illustration, whereas the scope of the invention is defined in the appended claims.

What is claimed is:

1. The modulation method which consists in impressing a high frequency wave and a low frequency wave on a translating device, suppressing a harmonic of the high frequency, and selecting the side-band products of the harmonic frequency and the impressed low frequency.

2. The method of wave transmission which consists in generating oscillations of a radio frequency and oscillations of an audio frequency, impressing both the radio frequency and the audio frequency oscillations on a modulating device, adjusting the modulating device so that no even harmonics of the fundamental radio frequency appear in the output of the device, and selecting the side-bands of one even harmonic of said frequency.

3. The method of modulation which consists in impressing on a translating device oscillations of a radio frequnency and oscillations of another frequency, adjusting the translating device so that no even harmonics of the fundamental radio frequency appear in the output of the device, and passing only the side-bands of one even harmonic of said frequency.

4. The method of producing an electric current wave of high frequency with groups of amplitude pulsations corresponding to the pulsations of a modulating wave, which consists in generating oscillations of a high frequency, impressing the high frequency oscillations and the modulating wave on a translating device, adjusting the translating device so that no even harmonics of the fundamental high frequency appear in the output of the device, and selecting the side-bands of one even harmonic of said frequency.

5. The method of carrier suppression modulation which consists in impressing oscillations of a radio frequency and the modulating oscillations on a translating device, adjusting the translating device so that no even harmonics of the fundamental radio frequency appear in the output of the device, and selecting the side-bands of one even harmonic of said frequency.

6. In a translating circuit, a translating device having a non-linear but symmetrical characteristic, means for impressing oscillations of a high frequency on said translating device, means for impressing oscillations of another frequency thereon, means for impressing on said translating device an auxiliary voltage corresponding to the point of symmetry of the characteristic, whereby no even harmonics of the high frequency appear in the output of the device, and means for selecting the side-bands of one even harmonic of the high frequency.

7. In a translating system, a three-electrode vacuum tube having a non-linear but symmetrical characteristic, an input circuit and an output circuit therefor, means for impressing oscillations of a high frequency on said input circuit, means for impressing oscillations of another frequency thereon, means for adjusting the normal mean potential on the grid of said vacuum tube to the point of symmetry of the characteristic of the tube, whereby no even harmonics of the high frequency appear in said output circuit, and means for selecting the side-bands of one even harmonic of the high frequency.

8. In a translating system comprising a translating device having a non-linear but symmetrical characteristic, an input and an output circuit, and sources of radio frequency and audio frequency energy associated with the input circuit, the method of producing a modulated output with the carrier suppressed, which consists in impressing the

radio frequency and the audio frequency energy on the input circuit, impressing on said circuit an auxiliary voltage of such value that as the mean input voltage varies with the variation of the audio frequency energy a certain harmonic of the radio frequency in the output circuit will undergo a reversal of 180° and the amplitude of the harmonic wave will be zero when the amplitude of the audio frequency wave is zero, and selecting in the output circuit the modulated certain harmonic of the radio frequency.

9. In a translating system comprising a three-electrode vacuum tube having a non-linear but substantially symmetrical characteristic, an input and an output circuit therefor, and sources of radio frequency and signal energy associated with the input circuit, the method of producing a modulated output with the carrier suppressed, which consists in impressing the radio frequency and the signal energy on the input circuit, biasing the grid of the tube so that its normal mean potential corresponds to the symmetrical mean of the characteristic of the tube for a given harmonic of the fundamental radio frequency, and selecting in the output circuit the modulated given harmonic.

10. A translating system consisting of a single three-electrode vacuum tube having a non-linear but substantially symmetrical characteristic, an input circuit and an output circuit therefor, means for impressing a high frequency alternating voltage on said input circuit, means for impressing on the grid of said tube a biasing voltage such that the normal mean grid potential corresponds to the symmetrical mean of the characteristic for a given harmonic of the carrier frequency, and means in said output circuit for selecting the modulated given harmonic.

In testimony whereof, I have signed my name to this specification this 10th day of September, 1927.

RALPH K. POTTER.