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METHOD FOR RADIO TRANSMISSION

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Fig. 1

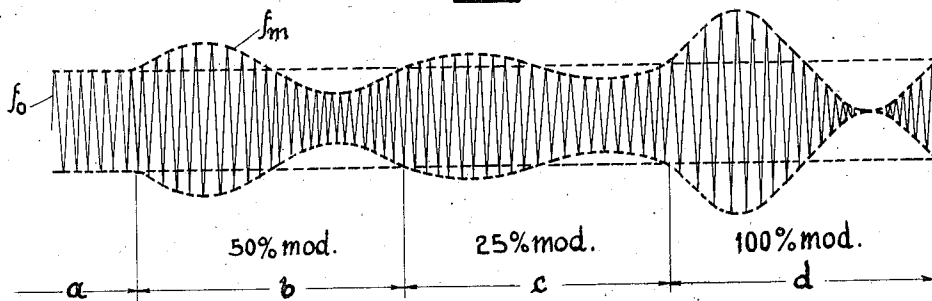


Fig. 2

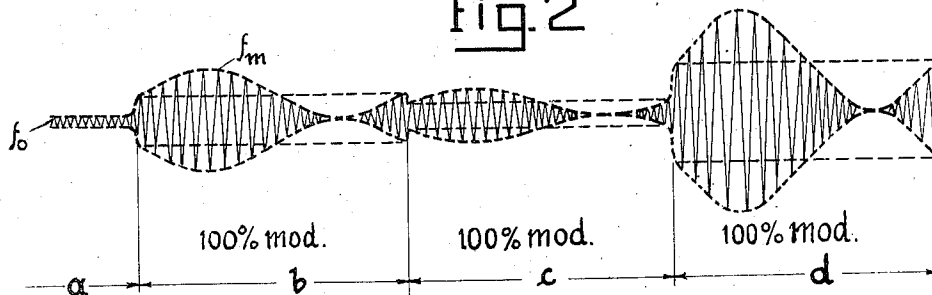
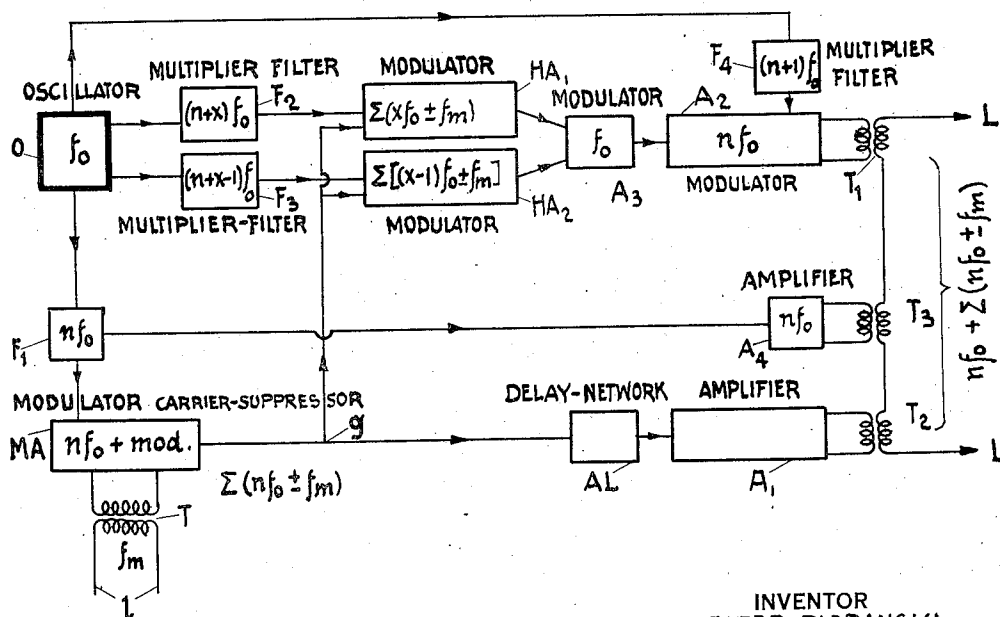


Fig. 3



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## UNITED STATES PATENT OFFICE

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## METHOD FOR RADIO TRANSMISSION

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This invention relates to a novel method and a system for transmitting radio signals, more particularly for modulated transmission such as transmission of broadcasting programs and the like.

The orthodox method of transmission used in broadcasting today employing amplitude modulation of the high frequency wave serving as the transmitting carrier, possesses serious disadvantages due to a high expenditure of transmitting power during the intervals between transmission of signals and during the transmission of weak signal when the carrier power is only partially modulated.

The invention has for its object to provide a novel and improved method and system for transmission of modulated radio frequency energy which is substantially devoid of the disadvantages inherent in systems and methods hitherto used in the art and which insures a maximum efficiency and utilization of the transmitting power to the fullest extent possible and during the entire transmission period.

The invention will be more fully explained in the following detailed description taken with reference to the accompanying drawing wherein I have illustrated schematically one way of carrying out the novel method of the invention.

Figures 1 and 2 of the drawing represent curves illustrative of the novel method of transmission according to the invention; and

Figure 3 shows in a schematic manner a modulated carrier transmission system for carrying out the novel method according to the invention.

As pointed out, the invention principally involves the provision of an improved modulating system in which the carrier frequency is permanently fully utilized, or in other words, deeply modulated preferably up to 100% or close to 100% modulation. More particularly, the invention involves the provision of a method and means whereby in order to reproduce loud and weak signals, such as occur during the "piano" and "forte" passages of an orchestral transmission, the carrier is automatically reduced or increased in such a manner as to permanently maintain substantially full or 100% modulation and utilization of the transmitting power to the fullest extent possible, resulting in a great saving and economy of transmission power as compared with systems and methods heretofore employed in the art.

As is well known, the amplitude modulated

carrier wave may be represented by the following theoretical formula:

$$b = B \sin \omega_0 t + mB \sin \omega_0 t \sin pt.$$

Wherein B represents the average carrier amplitude (unmodulated carrier),  $\omega_0 = 2\pi f_0$ ,  $f_0$  being the carrier frequency,  $t$  represents time,  $m$  represents the degree of modulation ( $m=1$  for 100% modulation), and  $p = 2\pi f_m$  wherein  $f_m$  represents the modulating frequency which in the example is assumed to be a single sinusoidal frequency but which in actual transmission may be comprised of a plurality of single frequencies making up a complex modulated wave such as obtained in transmission of speech and musical programs, and  $b$  represents the amplitude of the modulated carrier.

In accordance with my invention, the degree of modulation is maintained constant preferably equal to or close to 100% and the carrier frequency is varied for the transmission and reproduction of weak and loud signals. The above formula for the modulated carrier wave is thus modified and assumes the following form:

$$b = KB \sin \omega_0 t + B \sin \omega_0 t \sin pt$$

wherein K is a constant indicating the percentage of modulation. Thus for example, for K equal to 1.1, the modulation is obviously permanently about 90%; that is, close to the fullest possible utilization, resulting in maximum transmission efficiency and in large saving of transmission power. In this manner it is possible to reduce the carrier power to about one-quarter of the power required in accordance with the older methods and systems of transmission.

Referring to Figures 1 and 2, I have shown curves representing the modulated carrier according to the old method (Fig. 1) and according to the novel method as described by the present invention (Fig. 2).

As shown in Figure 1, the amplitude of the carrier  $f_0$  varies in accordance with the modulating wave  $f_m$ , the latter being the enveloping curve of the carrier amplitudes in the manner as is well known. In the example as illustrated, the carrier is unmodulated during the time period  $a$ , 50% modulated during the period  $b$ , 25% modulated during the period  $c$ , and 100% modulated during the period  $d$ . As is readily seen, the carrier power is fully utilized only during the period  $d$ ; that is, when 100% modulated, while during the remaining periods only a portion of the carrier wave energy is actually utilized for the transmission of the signalling or modulating frequen-

cies, resulting in low efficiency of the transmission, as pointed out.

Referring to Figure 2 which illustrates the modulated carrier in accordance with the invention, the carrier amplitude varies during the different transmitting periods  $a$  to  $d$  in such a manner as to permanently maintain 100% or substantially 100% modulation, resulting in the fullest and most efficient utilization of the transmitting power as is understood. Thus, during the period  $a$  the carrier amplitude is maintained at a very small value. During the period  $b$ , the carrier is equal to one-half of the carrier  $f_0$  as shown in Figure 1, the result being a 100% modulation for the same modulating frequency  $f_m$ . In a similar manner during the period  $c$ , the carrier amplitude is automatically changed to one-quarter of the carrier  $f_0$  again resulting in a 100% modulation, while the period  $d$  corresponds to period  $d$  according to Figure 1. In this manner it is seen that by the employment of a varying or "floating" carrier, the degree of modulation may be maintained constant; that is, practically substantially equal to 100% while the variation of the signal amplitudes is obtained by an automatic variation of the carrier amplitudes as described.

Referring to Figure 3, I have shown schematically and by way of example, a carrier transmitting system for carrying out the novel method of the invention as described hereinbefore. In this figure, O represents a primary or driving oscillator which may be of any type such as a vacuum tube oscillator, crystal controlled oscillator, etc. The oscillator O serves to produce a fundamental or basic carrier frequency  $f_0$ . Items  $F_1$ ,  $F_2$ ,  $F_3$ , and  $F_4$  represent combined frequency multipliers and filter devices of known design serving for transforming the basic frequency  $f_0$  to a desired high harmonic as will be described in more detail hereinafter. For this purpose any well known type of frequency changing device may be provided such as the well known harmonic frequency multipliers utilizing vacuum tubes with output current distortion and filtering means for segregating a desired harmonic from the distorted current wave. But it is understood that any other type of frequency multiplier, such as iron core frequency transformers or impulse excited frequency changers may be provided for the purpose of the invention. The different devices and elements used in a system described by Figure 3 have only been indicated schematically in the drawing as it is understood that their construction and design is well known to those skilled in the art and is in no way necessary for the understanding of the invention comprising the combination and association of a number of elements in a specific cooperating manner for carrying out the novel method and for obtaining the desired new results set forth hereinbefore.

In a similar manner, items  $HA_1$  and  $HA_2$  indicated as modulators, represent frequency changers of the superheterodyne type by which a given frequency is transposed or shifted to a different place in the frequency scale by the production of sum or difference combination frequencies.

I have furthermore shown at MA a modulator which may be a vacuum tube modulator of known type and design to which the modulating frequencies such as the current supplied from a microphone or other translating device are applied through an incoming line I and by means of a transformer T. The modulator MA serves to modulate a harmonic  $nf_0$  of the carrier fre-

quency  $f_0$  obtained by means of the frequency multiplier  $F_1$  in accordance with the modulating frequency  $f_m$  supplied by the transformer T. The modulator MA further is of special type such as a known balanced modulator in order to eliminate the carrier  $nf_0$  and to supply only the two modulated side bands in its output circuit. Modulators of this type (balanced modulators, etc.) are well known in the art and are used for instance extensively in the well known carrier suppressed side band transmission systems. Many known other arrangements of this type have been disclosed and used in the art and may be equally employed for the purpose of the present invention, as is well understood. The thus obtained modulated side bands with suppressed carrier are then applied through a suitable transmission circuit to the amplifier  $A_1$  for further amplification after passing an arrangement indicated at AL to be described later. From the amplifier  $A_1$ , the amplified side band frequencies are applied through coupling transformer  $T_2$  to the output circuit L—L which may be an antenna circuit (in case of radio transmission) or a transmitting line (in case of wired wireless transmission), the input circuit of a further amplifier, or similar apparatus or utilization circuit, as is readily understood.

I have furthermore shown means for restoring the carrier varying in proportion to the side band energy. For this purpose a portion of the modulated side band energy  $nf_0 \pm f_m$  or  $\Sigma(nf_0 \pm f_m)$  respectively, (wherein  $\Sigma$  stands for the sum of all the side frequencies in a known manner if the modulating signal comprises more than a single frequency  $f_m$  as assumed above), supplied by the modulator MA is derived from point  $g$  of the output circuit and applied to a pair of modulators  $HA_1$  and  $HA_2$  of the superheterodyne or similar type in which the frequencies  $\Sigma(nf_0 \pm f_m)$  are changed to intermediate frequencies  $\Sigma(xf_0 \pm f_m)$  and  $\Sigma[(x-1)f_0 \pm f_m]$ , respectively, by superimposition with the heterodyning frequencies supplied by the multipliers  $F_2$  and  $F_3$ , respectively, producing harmonics  $(n+x)f_0$  and  $(n+x-1)f_0$ , respectively, of the carrier  $f_0$  supplied by the driving oscillator O. The thus obtained two intermediate frequencies in the heterodyne modulators  $HA_1$  and  $HA_2$  are then in turn combined by means of a further heterodyne modulator  $A_3$  to yield a third intermediate frequency which by proper choice of the heterodyning frequencies  $(n+x)f_0$  and  $(n+x-1)f_0$  may for instance be equal to the fundamental frequency  $f_0$  of oscillator O. It can be shown that in the third modulator or intermediate amplifier  $A_3$  the carrier frequency reappears and that its amplitude varies in proportion to the modulation side bands. Thus assuming that there are present in  $HA_1$  the side bands  $+B/2 \cos(\omega_1 - p)t - B/2 \cos(\omega_1 + p)t$  for the frequency  $\omega_1 = 2\pi \times f_0$  and that in  $HA_2$  the same side bands for the other frequency  $\omega_2 = 2\pi(x-1)f_0$  are equal to

$$+B/2 \cos(\omega_2 - p)t - B/2 \cos(\omega_2 + p)t, \quad 65$$

the beating together of the two in the amplifier modulator  $A_3$  will result in the following:

$$\begin{aligned} iA_3 &= a[B/2 \cos(\omega_1 - p)t - B/2 \cos(\omega_1 + p)t + B/2 \cos(\omega_2 - p)t - B/2 \cos(\omega_2 + p)t] \\ &= aB^2/2 \cos(\omega_2 - \omega_1)t - aB^2/4 \cos(\omega_2 - \omega_1 - 2p)t \\ &\quad - aB^2/4 \cos(\omega_2 - \omega_1 + 2p)t + \dots \end{aligned} \quad 75$$

The frequency

$$\frac{\omega_2 - \omega_1}{2\pi}$$

may for instance be equal to the fundamental frequency  $f_0$  and the above formula indicates that this restored carrier is twice as great as the side bands of the double modulation frequency  $aB^2/4 \cos(\omega_2 - \omega_1 \pm 2f_m)t$ .

For more than one modulating frequency as assumed in the above case, the carrier will be correspondingly greater in comparison with the side bands of double frequency. As is understood, the side bands of double frequencies and other frequencies appearing as a result of cross modulation can be easily eliminated by using a type of amplifier  $A_3$  with a sharp cut-off such as an amplifier with a very high peak or sharp resonance curve or any other type of filtering device known may be used for this purpose as is well understood. In this manner only the restored carrier shall appear in the output of the amplifier  $A_3$ . This carrier can then be changed by a further balancing process by means of a modulator amplifier  $A_2$ , whereby the heterodyning frequency  $(n+1)f_0$  is supplied from the driving oscillator  $O$  through a frequency multiplying circuit  $F_4$ , to the frequency of the side bands in the amplifier  $A_1$  and combined therewith in the common output circuit  $L-L$  such as by means of a coupling transformer  $T_1$  as shown.

In this manner as is seen, the output circuit  $L-L$  will carry currents of the modulated side bands  $\Sigma B \cos(n\omega_0 \pm f_m)t$  and the carrier  $KB \sin n\omega_0 t$ , where  $K$  represents the modulation index remaining practically constant.

It is obvious from the above that the restored carrier will not necessarily be directly proportional to the coefficient  $B$  but may be proportional to  $B^2$ . This condition may be avoided by a suitable design of the frequency changing arrangement  $A_3$ . The term  $B^2$  appears only if square law detection is used. Practically the coefficient of the restored carrier shall be for instance  $KB^{1.1}$  in case of using a linear detection or rectification. From this it is clear that weak signals may be over-modulated (carrier too low) and therefore it is advantageous in order to insure satisfactory operation of the system to supply a small component of the carrier frequency directly to the output circuit through an amplifier  $A_4$  and coupling transformer  $T_3$  as shown in the drawing. This small carrier component corresponds to the unmodulated carrier during the period  $a$ , as shown in Fig. 2.

In the above description it is assumed that the arrangement works practically without appreciable time delay; that is, that the necessary carrier in the output circuit  $L-L$  appears simultaneously with the corresponding side bands. If, however, a time delay is introduced by the amplifier  $A_2$  or  $A_3$  or any other element in the circuit in order to smooth out the variations of the carrier, it becomes necessary to provide a similar time delay device in the circuit carrying the side band frequencies such as the artificial line  $AL$  shown in the drawing and mentioned above. However, the artificial network  $AL$  may be omitted if the time delay is not required.

As seen from the above, the method according to the invention as described, principally involves the double heterodyning of portions of the side band energy after suppression of the carrier frequency and the beating together of the thus obtained intermediate frequencies to restore the

carrier frequency varying in accordance with the side band energy and the combination of the restored carrier with the original side band frequencies in a common output circuit. The intermediate frequencies may be chosen in such a manner as to deliver directly the output frequencies in which case the heterodyne circuit  $F_4$  and the amplifier  $A_2$  may be dispensed with as is understood. Alternatively, the output carrier frequency may be obtained by frequency multiplication; that is, of the frequency obtained by beating together the two intermediate frequencies supplied by the heterodyne modulators  $HA_1$  and  $HA_2$ . It is furthermore possible to use a primary modulator  $MA$  which suppresses the carrier only to a certain extent, leaving a small carrier component which is transmitted into the output circuit  $L-L$  through the coupling transformer  $T_2$  in which case the amplifier  $A_4$  may be dispensed with, as is readily understood.

While I have described my invention specifically in connection with the embodiment shown in the drawing, it is understood that the novel methods and arrangements as disclosed may be used in connection with various systems and methods of transmission of wireless signals. Thus for instance, the above system can be used with equal advantage for one side band transmission with a variable or "floating" carrier in accordance with the invention. In the latter case the modulator  $MA$  must be of suitable type and design for suppression of the carrier and one of the side bands whereby the remaining side band such as the upper side band  $\Sigma(nf_0 + f_m)$  is then combined in  $HA_1$  and  $HA_2$  with the harmonic frequency waves  $(n+x)f_0$  and  $(n+x-1)f_0$  supplied from the multipliers  $F_2$  and  $F_3$ , respectively, resulting in combination frequency waves  $\Sigma xf_0 + f_m$  and

$$\Sigma[(x-1)f_0 + f_m],$$

in a manner similar as described to producing a reconstructed carrier in the modulator varying in proportion to the strength of the modulating signal frequencies.

It is obvious therefore that the invention as described is subject to various modifications and variations coming within its broad scope and spirit, and I do not wish to be limited to any specific arrangements and methods disclosed short of the scope as expressed in the appended claims.

I claim:

1. A method of signalling which consists in modulating a carrier wave in accordance with a modulating wave to produce modulated and unmodulated components, suppressing the unmodulated carrier component, reconstructing an unmodulated carrier component varying in proportion to the strength of said modulating wave from energies derived from the carrier wave and modulated component, and combining said reconstructed unmodulated component with said modulated component to secure a modulated carrier wave having a substantially constant ratio of its modulated and unmodulated components.

2. A signalling system comprising means for modulating a carrier wave in accordance with a modulating wave to produce a modulated component with suppression of the carrier, further means for reconstructing a carrier varying in proportion to the strength of said modulating wave from energies derived from the original carrier wave and said modulated component, and means for combining the reconstructed carrier with said modulated component to secure a modulated carrier wave having a substantially con-

stant ratio of its modulated and unmodulated components.

3. A method of signalling consisting in modulating a carrier wave in accordance with a modulating wave to produce modulated and unmodulated components, suppressing the unmodulated component, reconstructing an unmodulated carrier component varying in proportion to the strength of said modulating wave by means of energy derived from said modulated component, and combining said reconstructed unmodulated component with said modulated component to produce a resultant modulated carrier wave having a substantially constant ratio of its modulated and unmodulated components.

4. A signalling system comprising means for modulating a carrier wave in accordance with a modulating wave to produce a modulated component with suppression of the carrier, a further means for reconstructing a carrier varying in proportion to the strength of said modulating wave by means of energy derived from said modulated component, and means for combining said reconstructed carrier with said modulated component to produce a resultant modulated carrier wave having substantially constant ratio of its modulated and unmodulated components.

5. A method of signalling consisting in producing carrier suppressed modulation side band signalling frequencies, beating said side band frequencies with different harmonics of said carrier frequency, and beating together resultant intermediate frequencies to reconstruct therefrom, a carrier frequency of average amplitude varying substantially in accordance with the energy of said side bands and combining said reconstructed carrier frequency with said side band frequencies.

6. A method of signalling consisting in producing a carrier frequency and a plurality of harmonics thereof, modulating said carrier frequency to produce carrier suppressed modulation side band signaling frequencies, separately beating said side band frequencies with different harmonics of said carrier to produce combination intermediate frequencies, beating said combination frequencies to reconstruct therefrom a resultant frequency equal to the carrier frequency and having an average amplitude varying in accordance with the energy of said side band frequencies, and combining said reconstructed carrier frequency with said side band frequencies to obtain a modulated carrier of substantially constant degree of modulation for varying strength of the modulating signals.

7. A method of signalling consisting in producing a carrier frequency and a plurality of harmonics thereof, modulating said carrier to pro-

duce carrier suppressed side band signalling frequencies, separately beating said side band frequencies with different harmonics of said carrier to produce a plurality of combination frequencies, beating said combination frequencies to reconstruct therefrom a resultant frequency equal to said carrier frequency and of varying amplitude in accordance with the energy of said side band frequencies, and combining said reconstructed carrier frequency with said side band frequencies to obtain a modulated carrier frequency of substantially 100% modulation for varying signal strength.

8. A carrier transmission system comprising a generator for producing a fundamental carrier frequency, means for modulating said carrier frequency to produce carrier suppressed side band signalling frequencies, means for producing a plurality of harmonics of said carrier frequency, means for separately beating said side band frequencies with said harmonics to derive a plurality of intermediate frequencies, further means for beating together said intermediate frequencies to reconstruct therefrom a further intermediate frequency equal to said carrier frequency and of varying amplitude in accordance with the energy of said side band frequencies, an output circuit, means for superimposing therein said side band frequencies and said reconstructed carrier frequency, the variations of said reconstructed carrier frequency being such as to maintain a constant degree of modulation of the combined carrier and side bands in said output circuit.

9. A carrier transmission system comprising a generator for producing a fundamental carrier frequency, means for modulating said carrier frequency to produce carrier suppressed side band signalling frequencies, means for producing a plurality of harmonics of said carrier frequency, means for separately beating said side band frequencies with different harmonics of said carrier frequency to derive a plurality of intermediate frequencies, further means for beating together a pair of intermediate frequencies to reconstruct therefrom a resultant frequency equal to said carrier frequency and of varying amplitude in accordance with the energy of said side bands, an output circuit, means for superimposing therein said side band frequencies and said reconstructed carrier frequency, the variations of said reconstructed carrier being such as to maintain a constant degree of modulation substantially equal to 100% of the combined reconstructed carrier and side band frequency currents in said output circuit.

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