Aug. 4, 1936. A. G. COOLEY 2,049,424

ELECTRIC WAVE SIGNALING

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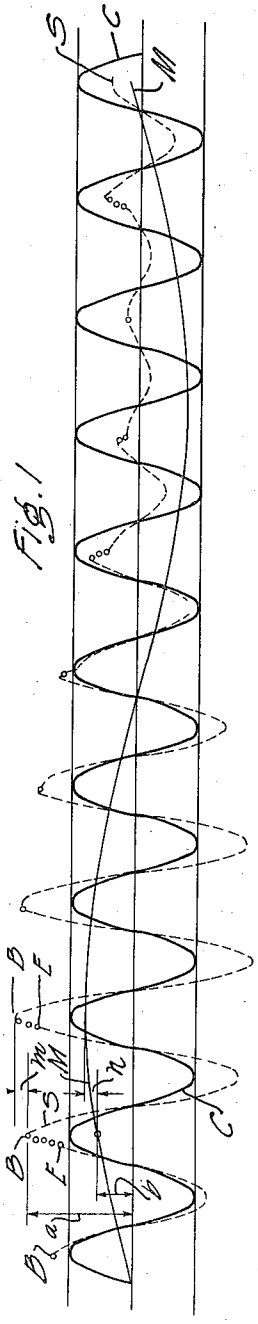


Fig. 1

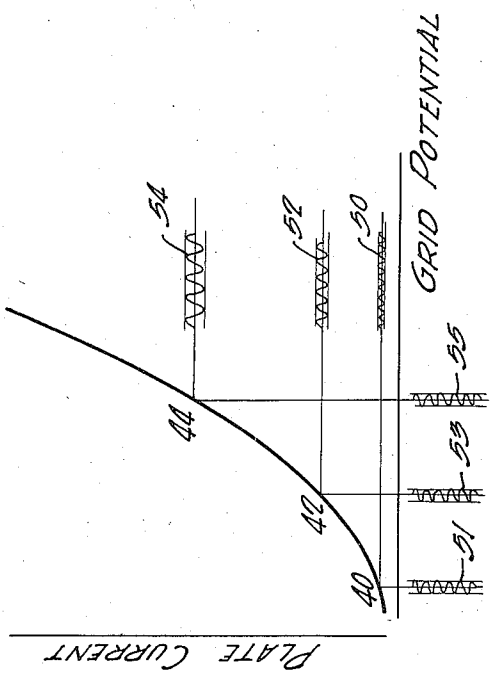


Fig. 4

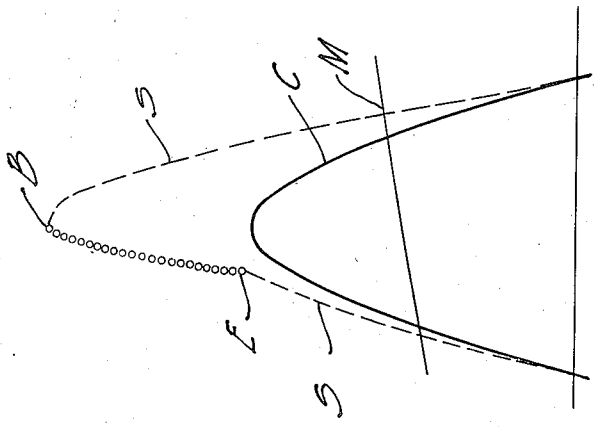


Fig. 2

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Fig. 3

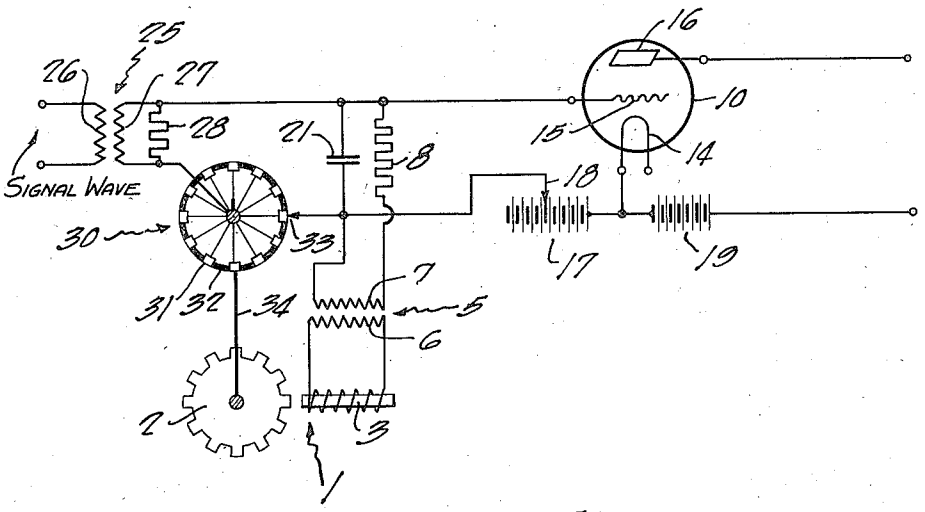
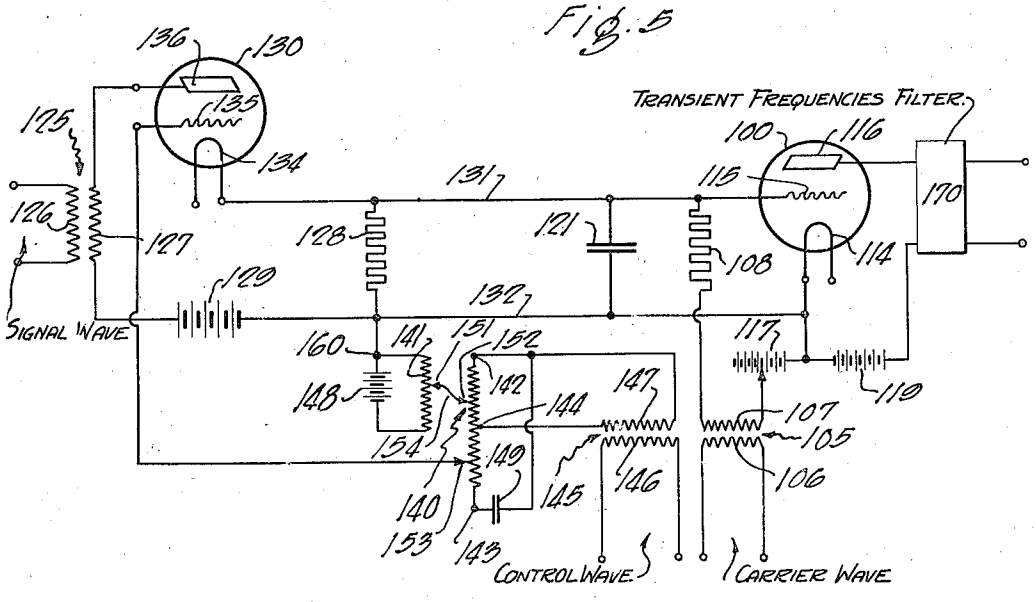


Fig. 5



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ELECTRIC WAVE SIGNALING

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16 Claims. (Cl. 179—171)

It is a well known expedient in the art of electric wave signaling, as for example radio telephony, to combine two oscillations, one of constant high frequency, commonly called "carrier wave", and one of much lower frequency which represents the signals to be transmitted and is usually referred to as "modulating wave". The resulting wave, with the modulating wave impressed upon the carrier wave, is referred to as the "modulated carrier wave", and can be resolved into a wave of a frequency equal to the sum of the two component frequencies, a second wave of a frequency equal to the difference of these two component frequencies, and a wave of the frequency of the stronger of the two waves. Consequently, if the frequency of the modulating wave varies (as for example in telephony where it conforms to the frequencies comprised in the acoustic oscillations to be transmitted) the modulated carrier covers a frequency range of at least twice the highest modulating frequency, which accounts for example for the well known difficulty of allotting a sufficient number of transmitting channels for purposes of radio broadcasting.

It is the primary object of the present invention to provide a method, and means for carrying out that method, of impressing signal waves upon a carrier wave substantially without introducing powerful accompanying frequencies or so-called side bands, so that only a narrow transmission channel is required. Other objects will be apparent from the following description of the underlying principle and of several concrete embodiments of the invention by way of explaining its genus, the description referring to drawings, in which

Fig. 1 is a diagram of carrier wave, signal wave and the combination thereof obtained according to the present invention;

Fig. 2 shows somewhat enlarged a portion of Fig. 1;

Fig. 3 is a circuit connection diagram of one embodiment of the present invention;

Fig. 4 shows a grid voltage-plate current diagram of an electron discharge device as used in the present invention; and

Fig. 5 is a circuit diagram of another embodiment of the invention.

Whereas the previously known modulated carrier wave is produced by continually combining the modulating and carrying waves, the carrier according to the present invention (which will herein be referred to as "signaled carrier" in order to distinguish it from the "modulated carrier" of the prior art), is produced by regulating the amplitudes of successive cycles of a sinusoidal carrier wave in accordance with the configuration of the modulating wave, whereby the amplitudes are set and regulated only at certain predetermined points during comparatively short adjustable periods of certain cycles of the carrier wave. If adjoining cycles are to have different amplitudes, the change takes place within a certain transient period section, each cycle otherwise retaining its sinusoidal shape, although the amplitudes differ. In this manner, the frequency and sinusoidal shape of the signaled carrier are retained over the major portion of the cycle, the signals being transmitted substantially only by varying the amplitude of the signaled carrier wave of constant frequency. Only the carrier frequency need be transmitted, since the frequencies which are introduced by the transient period sections are unnecessary for reception and may therefore be filtered out. Besides that, they are of such low power that they can in many cases be ignored.

This new way of impressing signal waves upon a carrier wave is illustrated in Figs. 1 and 2, where C is the sinusoidal carrier wave of constant frequency, M the modulating signal wave and S the signaled wave. Each cycle of S is sinusoidal from B to E, whereas the amplitudes of consecutive cycles vary in accordance with the momentary value of the signal wave at the beginning of each carrier cycle, if B to E is called a signaled carrier cycle. Thus, presuming that each sinusoidal period section starts at the apex of a cycle, if a certain signaled cycle has during that sinusoidal section an amplitude a at B, and the signal wave increases during that cycle from b to $b+n$, the next transient section E B brings the amplitude of the signaled carrier to $a+m$, m corresponding to the increase n of the signal wave. In this manner, every cycle is during the transient period section adjusted to the momentary value of the signal wave at that time, whereas no change takes place during the section B E which is very much longer and during which the signaled wave, uninfluenced by the signal wave, retains its sinusoidal shape with the amplitude acquired during the last transient section.

Referring to Fig. 3, an arrangement for carrying out this new method of modulating a carrier wave will be described. A carrier frequency generator 1 with rotor 2 and armature winding 3 supplies a carrier wave to a transformer 5 with primary 6 and secondary 7. One terminal of secondary 7 is connected through a high resistance 8, to the grid 15 of an electron discharge device

10. The other side of the secondary 7 is connected to the filament 14 through an adjustable biasing battery 17. Another battery 19 is in the output circuit of the electron discharge tube 10. Secondary 7 and resistance 8 are shunted by a condenser 21. Incoming signal waves are supplied, for example, through a transformer 25 with primary 26 and secondary 27, the secondary 27 being connected to the terminals of a resistance 28. One terminal of resistance 28 is connected to condenser 21, whereas the other terminal leads to a mechanical interrupter with contact segments 31 separated by insulations 32, the segments being connected among themselves and to the second terminal of resistance 28 whereas a sliding contact 33 leads to condenser 21 and secondary 7. Interrupter 30 is mechanically or otherwise driven in synchronism with generator 2, as indicated in the drawing by a common shaft 34 for 2 and 30. Generator and interrupter are so arranged that connection between resistance 28 and condenser 21 is established only during a comparatively short period when the amplitude of the carrier wave supplied by 2 is high.

Any incoming signal waves determine a certain varying potential drop across resistance 28 which supplies condenser 21 with a correspondingly varying potential, but only during the periods when the interrupter 30 establishes connection between resistance and condenser. Therefore, the charge of condenser 21 during each period when it is connected to the signal input circuit, is determined by the potential drop across coupling resistance 28, which is proportionate to the momentary amplitude of the incoming signal wave. In other words, referring now again to Figs. 1 and 2, condenser 21 and coupling resistance 28 are connected during the transient period section E B, whereas during the sinusoidal period section B E, the signal input circuit is disconnected from the input circuit of tube 10. Consequently, the average voltage across condenser 21, and therefore across the input circuit of tube 10, is set at each transient period section according to the momentary value of the signal wave, and remains substantially constant during the remaining section B E of each cycle, since the only possible leakage path is through resistance 8 which can be dimensioned at such a high value that condenser 21 drains very slowly so that the section B E substantially retains its sinusoidal shape, and its amplitude is determined and set during the preceding transient period E B.

The charge on condenser 21 therefore determines for each cycle of the signaled wave the mean potential of grid 15. This mean grid potential is shifted during each transient period section (provided the signal amplitude changes at all) proportionally to the momentary signal potential at that time across resistance 28, and the carrier wave is amplified accordingly. Fig. 4 shows how the shifting of the mean grid potential determines the amplification of the signaled wave in the output circuit of tube 10. If the grid potential has a lowest value at 40 of the conventional grid potential-plate current curve, the amplification is comparatively low, as indicated by the conventional curve 51 symbolizing the grid potential in comparison to curve 50 representing the plate current. If the mean grid potential is shifted to a point 42 by a higher signal potential impressed across resistance 28, the amplification is increased as shown by curves 53 and 52, and with the grid potential at 44, the amplification is still higher. If the average amplitude of the signaled carrier is represented by curve 52, the signal wave may be utilized to shift the mean grid potential, and with it the amplitude of the signaled carrier in the output circuit, between two extremes represented by curves 50 and 54, without causing volume distortion, provided the corresponding section 40 to 44 of the curve is parabolic and provided that the amplitude of the carrier wave 51, 53, or 55 is low. This is due to the well known fact that the voltage amplification depends upon the first derivative (or the steepness) of the curve, and the first derivative of a parabolic curve increases linearly. The working range of the curve, or the mean grid potential corresponding to point 42, can be set with the aid of variable grid voltage supply 17. It will now be understood that, due to the influence of the momentary signal amplitude upon the carrier wave during the transient section, which influence is substantially maintained during the ensuing sinusoidal section, the signaled carrier is composed of substantially sinusoidal and constant amplitude sections B E, connected by transient sections E B during which the amplitude is changed in accordance with the signal amplitude prevailing at that time.

Instead of employing to some extent mechanical means for producing a signaled carried according to the present invention, a purely electrical arrangement according to Fig. 5 can be used for the same purpose, especially in cases where the carrier frequency is high. Similar to the modification according to Fig. 3, an electron discharge device 100 with filament 114, grid 115 and plate 116 has an output circuit battery 119 and in the control circuit a grid biasing battery 117, a transformer secondary 107 and a high resistance 108 in series across the grid and filament terminals. Secondary 107 is part of a transformer 105 whose primary 106 is supplied with a sinusoidal carrier wave of suitable constant frequency. The signal waves are supplied to the primary 126 of a transformer 125, whose secondary 127 is on the one side connected to plate 136 of a second electron discharge device 130 and on the other side through plate battery 129 and conductor 132 to the filament 114 of tube 100. The filament 134 of tube 130 is connected to grid 115 of tube 100 by conductor 131 and across conductors 131 and 132 are a resistance 128 and a condenser 121. An auxiliary transformer 145 whose primary 146 is connected to a source of current having the same frequency, or a lower or higher harmonic thereof, as the carrier wave, supplies from its secondary 147 terminal 142 and tap 144 of a resistance 140, whose other terminal 143 is connected to 142 through a condenser 149. A conductor 154 with two slide contacts 151 and 152 leads from a potentiometer 141 with battery 148 to resistance 140. Terminal 160 of the potentiometer is connected to conductor 132. A slide contact 153 connects an adjustable point of resistance 140 to grid 135 of tube 130.

Condenser 121 and resistances 128 and 108 in the control circuit of tube 100 function similar to the corresponding elements 21, 28, and 8 of Fig. 3, but the method of impressing during the transient period the momentary signal amplitude upon resistance 128 is different. Transformer 145 supplies a current of the carrier frequency or a harmonic thereof, whereby the proper phase relation and amplitude can be obtained by adjusting slide contacts 152 and 153 in a man-

ner which will be readily understood, one half of resistance 140 being connected directly across secondary 147 whereas the other half is connected to the secondary in series with condenser 149. With the aid of potentiometer 141 and battery 148, a biasing potential is applied to grid 135. The grid potential is so adjusted that the grid normally stops flow of current from plate 136 to filament 134, but permits it if its potential rises sufficiently over the biasing potential, when signal current is permitted to flow to resistance 128. Since the current applied to the grid from transformer 145 is in adjustable relationship to the carrier current supplied to transformer 105, the period of increased potential of grid 135 and therefore charge of resistance 128 by the signal current is adjustably controlled by the carrier wave; in other words, the momentary signal amplitude can be applied to resistance 128 during a transient period recurring at certain predetermined intervals of the carrier wave, grid 135 operating as a trigger valve, which permits flow of current between plate 136 and filament 134 only during this period. The potential across resistance 128 and condenser 121 varies in accordance with the momentary amplitude of the signal wave, and the amplitudes of consecutive sinusoidal signaled carrier wave cycles are varied with the aid of condenser 121 and amplification tube 106, as described in connection with Fig. 3.

The length of the transient period section can be regulated by adjusting the biasing potential of grid 135; the lower the grid bias, the longer the transient section during which the potential supplied by transformer 145 surpasses the biasing potential.

The placing of the transient period section within a carrier cycle depends upon the phase relationship of the carrier wave and the wave impressed upon grid 135. Presuming that the currents in 105 and 145 are in phase, this phase relationship can be changed with the aid of contacts 152 and 153 and condenser 149. In order to keep the average differential gradient or slope of the transient period section as far as possible close to that of the sinusoidal carrier wave, (which is important in order to avoid higher frequencies) attention must be given to the rate of charge and discharge of condenser 121 which influences the shape of the transient curve. Care is therefore necessary in selecting a tube 130 with proper characteristics, suitable resistances 128 and 108 and a condenser 121 of corresponding dimensions. Although the relative characteristics of these elements permit many changes in accordance with prevailing conditions, I have found that for a carrier frequency of approximately 30,000 cycles a tube 130 of the "199 type", having three elements, a resistance 128 of 10,000 ohms, a resistance 108 of 100,000 ohms, and a condenser 121 of .0003 m. f. work satisfactorily.

If it is desired to have one transient period section per cycle, as shown in Figs. 1 and 2, the primary 106 and 146 can be supplied from the same source, which corresponds to one commutator segment per pole pair of the mechanical arrangement of Fig. 3. If it is, for example, desired to have a transient period section per half cycle, transformer 145 must be supplied with a frequency twice the carrier frequency. In other cases, where the signal frequency is low in comparison to the carrier frequency, it may be advantageous to have a transient period section only within every second, third or fourth cycle of the carrier wave, or even at greater intervals, in which case transformer 145 must be supplied with a subharmonic of the carrier frequency, or impulses occurring at subharmonic intervals.

Since in a system according to this invention only the frequency of the original sinusoidal carrier wave need be transmitted, the higher frequencies of low intensity which are due to the transient period may be filtered out, for example by a filter 170 of any suitable design in the output circuit of Fig. 5. In filtering and further amplifying the signaled carrier for transmission, it is essential that the decrement of the carrier frequency circuits is rather high, since otherwise the signaled carrier will tend to assume the characteristics of an ordinary modulated carrier with its wide range of frequencies.

It will be understood that many variations of the arrangements of Figs. 3 and 5 are possible within the scope of this invention. For example, condensers 21 or 121, respectively, may be replaced by an inductance coil for storing the charge intermediate the transient periods, or, in some cases, the filament battery 133 (Fig. 5) may have sufficient capacitance to replace condenser 121. Also, electronic or gas discharge devices having two, four or more electrodes have characteristics suitable for operation in the place of electronic tube 130.

It should be understood that the present disclosure is for the purpose of illustration only and that this invention includes all modifications and equivalents which fall within the scope of the appended claims.

I claim:

1. An electric signaling system comprising a source of substantially sinusoidal carrier current, an amplification circuit supplied from said source, means for changing the ratio of amplification of said current, during relatively brief predetermined period sections thereof, in accordance with a signal to be transmitted while otherwise maintaining the sinusoidal shape of said current, and means for operating said changing means in synchronism with said source.

2. An electric signaling system comprising an amplification circuit supplied from two sources of varying currents with different frequencies and regulating means controlled by both sources for adjusting the amplification of the current supplied by one source in accordance with the configuration of the current supplied by the other source, during regularly recurring relatively brief period sections coordinated with the cycles of the current supplied by said first source.

3. Electric signaling apparatus comprising means for supplying substantially sinusoidal high frequency oscillations of substantially constant wave length and amplitude, means for supplying signal oscillations of comparatively low frequency, and means for combining said two oscillations during definite, uniform and comparatively short sections within certain cycles of one of said oscillations.

4. Electric signaling apparatus comprising an amplification device, means for supplying high frequency oscillations and oscillations of comparatively low frequency to the input circuit of said device, and means for regulating the rate of amplification of said high frequency oscillations in proportion to the momentary value of said low frequency oscillations, during period sections of less than a quarter cycle at intervals of multiples of a half cycle.

5. Electric signaling apparatus comprising an electronic amplification device, means for applying high frequency voltages to the control electrode of said device, and regulating means supplying a potential proportionate to the momentary values of signal voltages to said control electrode during period sections at definite intervals in synchronism with said high frequency oscillations.

6. Electric signaling apparatus comprising an electronic amplification device, means for applying high frequency oscillations and signaling oscillations to the control electrode of said device, means for regulating the potential upon said electrode in accordance with the momentary values of said signaling oscillations during comparatively brief period sections at recurrent intervals synchronized with said high frequency oscillations, and means for substantially maintaining said potential intermediate said period sections.

7. Electric signaling apparatus comprising an electronic amplification device, means for supplying high frequency oscillations to the input terminals of said device, means for applying a potential proportionate to signal oscillations across said input terminals during comparatively brief period sections at definite intervals, and a reactance across said input terminals for substantially maintaining their potential during said intervals.

8. Apparatus for modulating the amplitude of a high frequency carrier wave in accordance with the configuration of a signaling wave, comprising an electronic amplifier supplied with said carrier wave, a contactor applying said signal wave to the input terminals of said amplifier during definitely spaced comparatively brief period sections in synchronism with said carrier wave, and a reactance across said terminals for substantially maintaining the input terminal potential intermediate said sections.

9. Electric signaling apparatus comprising an electronic amplification device, means for supplying a carrier current and a signaling current to the input terminals of said device, a reactance across said input terminals and electronic means for varying the potential across said reactance proportionate to the value of said signaling current, during intermittent period sections recurrent in synchronism with said carrier current.

10. Electric high frequency signaling apparatus comprising means supplying a carrier current of substantially constant frequency, means supplying a signal current, means for amplifying said carrier current, means for regulating the amplification of said carrier current proportionally to the value of the signal current prevailing during certain recurrent carrier current period sections and means for substantially maintaining the amplification intermediate said period sections to the last amplification determined by said regulating means.

11. Electric signaling apparatus comprising an amplification tube, means including a high resistance for impressing a carrier wave potential upon the grid of said tube, a condenser across grid and filament of said tube, means including an interrupter for intermittently impressing a signal wave potential across said condenser and means for operating said interrupter in synchronism with said carrier wave.

12. Electric signaling apparatus comprising an amplification tube, means including a high resistance for impressing a carrier wave potential upon the grid of said tube, a condenser across grid and filament of said tube, a resistance parallel to said condenser, a control tube whose plate circuit includes in series said resistance and a source of signal potential, and means for applying to the grid of said control tube a control potential in synchronism with said carrier potential.

13. The method of electric signaling which comprises producing a high frequency wave train and impressing signals thereon by varying the amplitudes of consecutive substantially sinusoidal wave sections of said train in accordance with varying signal amplitudes during relatively brief periods of the high frequency wave, whereby transient sections connecting said sinusoidal sections of differing amplitudes are produced.

14. Electric signaling apparatus comprising means for supplying high frequency oscillations, and means for varying the amplitude of said high frequency oscillations in accordance with signals, said means being synchronized with said supply means for changing during relatively brief, and uniformly recurrent sections of the high frequency oscillations the signal energy of said oscillations, whereby brief transient sections connecting consecutive longer sections of varying amplitudes but substantially sinusoidal wave form are produced.

15. The method of providing a modulated wave train, which comprises producing a train of substantially sinusoidal waves having substantially uniform amplitude, and impressing on said wave train signals by diversely varying the amplitudes of consecutive sinusoidal wave sections of said train during comparatively short periods of the wave train, whereby transient sections connecting said sinusoidal wave sections in accordance with the varying amplitudes of a modulating signal are produced.

16. The method of electric signaling which comprises producing a high frequency wave train and impressing on said train signals by varying the amplitudes of consecutive substantially sinusoidal wave sections of said train in accordance with the varying amplitudes of a signal, during periods of the high frequency wave train of less than a quarter cycle and at phase intervals of multiples of a half cycle of said train whereby transient sections connecting said sinusoidal sections of different amplitudes are produced.

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