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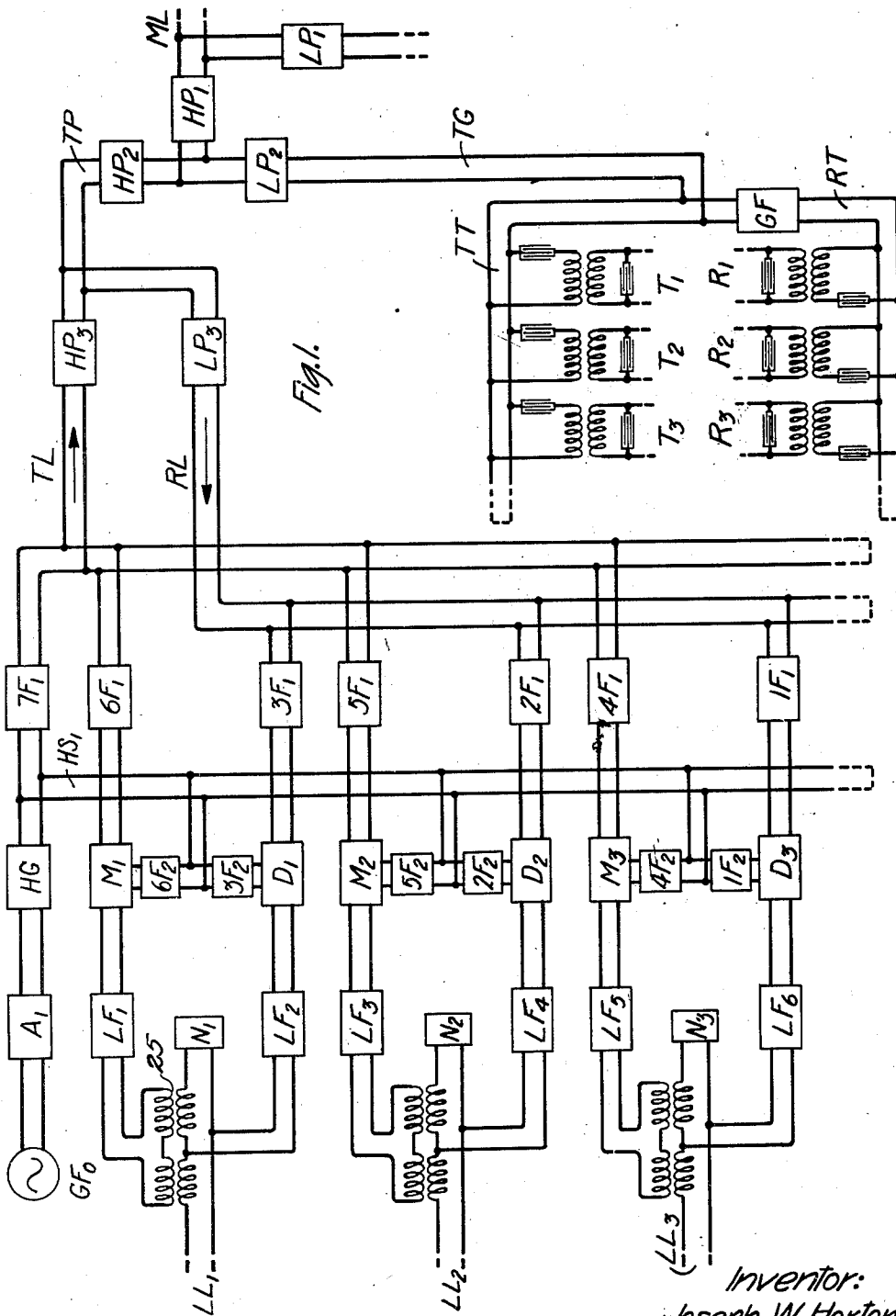
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GENERATION AND CONTROL OF ELECTRIC WAVES

Filed March 21, 1922

2 Sheets-Sheet 1



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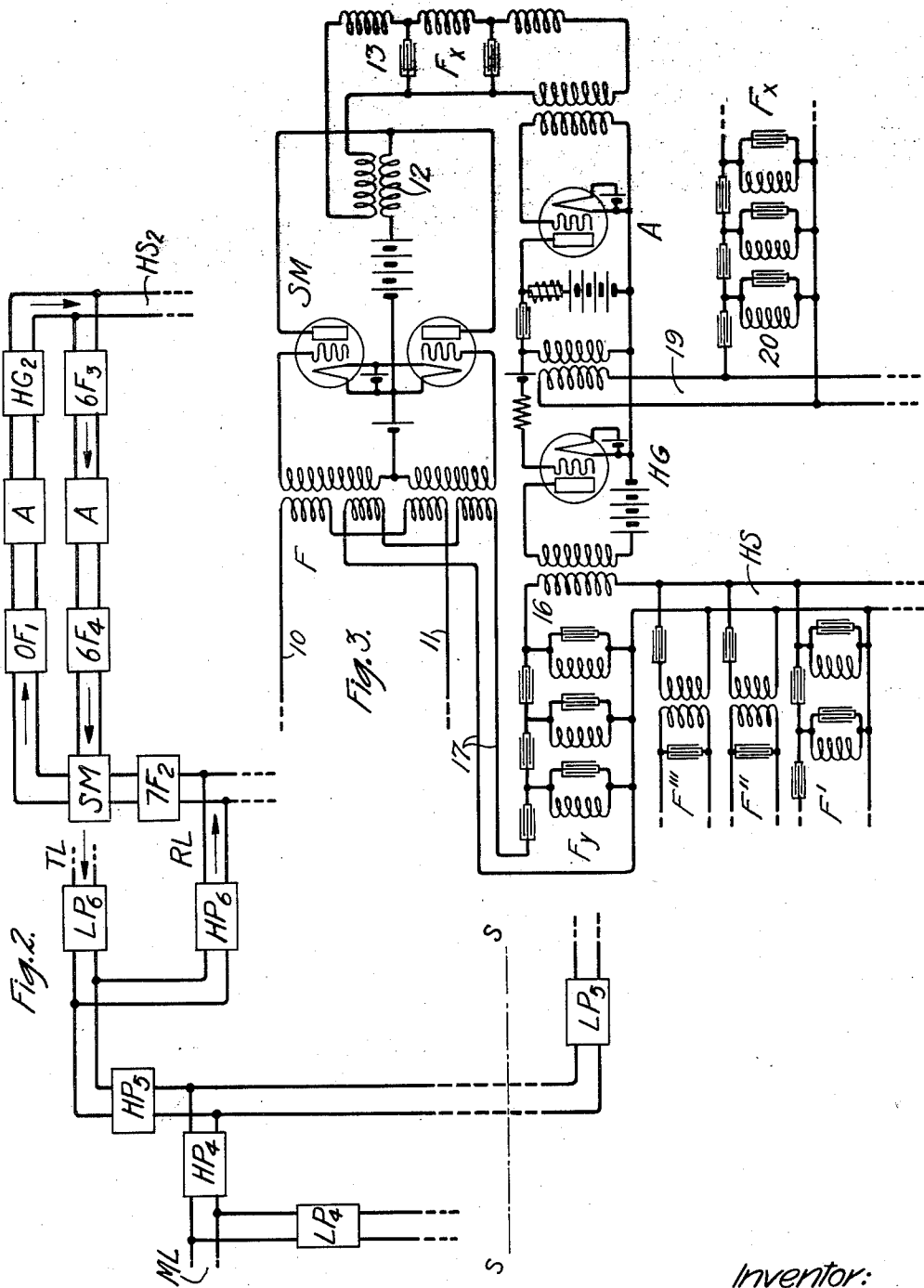
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## UNITED STATES PATENT OFFICE.

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## GENERATION AND CONTROL OF ELECTRIC WAVES.

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The present invention relates to the derivation of one or a plurality of waves of desired frequencies from a wave of given frequency, and more particularly the derivation of a wave of lower frequency or frequencies from a wave of given higher frequency, and the invention comprises both the means and the method or process concerned.

The invention further relates to the method and means of apply this frequency derivation or conversion to signal transmission or other kinds of transmission and control, as well as to the reproduction in general, and particularly at distant point or points, of waves bearing definite frequency relation to a master or control wave generated at a sending station.

The invention is particularly applicable to carrier wave transmission in which a wave of the carrier frequency is employed in the reception of the signals, since the invention affords a way of deriving the frequencies of several carriers to be employed at a receiving station, from a single frequency which may be higher than some or all of the carrier frequencies to be derived. The invention, however, while particularly adapted for such use is capable also of general application, as will be described.

The invention in its specific aspects involves the carrying out of a self-sustained cycle of operations by which a received wave of given frequency is continuously modulated by one or more of its frequency derivatives to produce the said or other derivatives. By derivatives is meant broadly a wave obtained or derived in some manner from the given wave although it may not be a component frequency of the given wave since the given wave may be and preferably is a pure sine wave of a single frequency. The derivative, however, bears a perfectly definite relation to the wave from which it is derived, which relation is determined by the nature and adjustment of the circuit elements employed.

The incoming wave from which waves of other frequencies are to be derived is impressed upon a modulator which has selective circuit elements connected to its output side for selecting one or more waves of frequencies different from that of the incoming wave. These selected waves may be vari-

ously treated, but at least one of them is either returned to the input side of the modulator or, as is preferably done, a harmonic frequency of one of the selected waves is so fed back to intermodulate with the incoming wave to produce continuous output waves of the frequencies desired. Amplification may be employed as desired and if there is sufficient amplification in the round-trip path, the action will be self-sustained and any number of derived frequencies bearing definite relation to the incoming frequency may be obtained by providing the necessary selective circuits and, of course, by properly adjusting the circuit.

A better understanding of the invention in both its broad and specific aspects will be afforded by the following detailed description of certain typical embodiments, and its various objects and features will be brought out as the description proceeds.

In the drawing, to which reference will now be made, Figs. 1 and 2 illustrate a carrier wave transmission system in which the invention is embodied and Fig. 3 represents a circuit suitable for use in the system of Figs. 1 and 2, but also capable of general application, for deriving from a given wave one or more other waves, some of which, at least, are of lower frequencies than the given wave.

Referring first to Fig. 3, the circuit 10, 11 is assumed to be carrying the wave of given frequency under control of which waves of other frequencies are to be generated. The wave in the incoming circuit 10, 11 is applied to a circuit comprising a number of elements associated serially in a manner to carry out a closed cycle of operations. This apparatus includes the balanced modulator SM which may be thought of as a sub-multiple generator since its function is to produce in its output circuit a definite sub-frequency of the wave incoming in the circuit 10, 11. This modulator may be of any suitable type but as illustrated it is of the type disclosed in the British Patent No. 151,928. A property of this circuit is that it produces the sum and difference frequencies of the impressed waves but does not transmit through its circuit the input wave in the form in which it is impressed. The output of the sub-multiple generator SM is connected to the filter 13 which

may be a band filter or, in some cases, a simple tuned circuit but is preferably a low-pass filter, as illustrated. This and the other filters shown throughout the drawings may be designed in accordance with the principles disclosed in the United States patent to G. A. Campbell, 1,227,113, issued May 22, 1917. Following the filter 13 may be an amplifier A to the output of which is connected the harmonic generating tube HG which leads into the filter 16 and this filter is in turn connected by way of the circuit 17 around to the input side of the modulator SM. The harmonic generator HG may be constructed and arranged to operate as described in the British patent No. 142,571. The filter 16 is shown as a band-pass filter which is the preferred type but, as will be explained later, a low-pass filter may be used, if preferred, and for some purposes a simple tuned circuit may be found sufficient in place of the filter 16 as well as in place of the filter 13. A circuit 19 in parallel with the input side of the harmonic generator HG is shown for diverting a portion of the amplified energy of the frequency transmitted through the filter 13, and one or more filters, such as 20, may be connected to this circuit and may lead to suitable work circuits. A branch circuit HS serving as a harmonic supply circuit is also shown leading from the input side of the filter 16, this circuit HS being provided with a number of selective branches  $F'$ ,  $F''$  and  $F'''$ , each of which may lead to a suitable work circuit.

In operation, the filter 13 will be arranged to pass selectively a definite frequency  $F_x$  lower than the frequency  $F$  of the wave incoming in the circuit 10, 11. The wave of the frequency  $F_x$ , after suitable amplification, is applied to the harmonic generator HG and one of its higher harmonics  $F_y$  is selectively transmitted through the filter 16. This filter is so designed that the harmonic  $F_y$ , which it selects, differs from the frequency  $F$  by the frequency  $F_x$  and it is preferable that the frequency  $F_y$  be lower than  $F$  by the amount  $F_x$ . There are thus applied to the input side of the modulator SM, two waves having respective frequencies  $F$  and  $F_y$ . These two frequencies combine in the modulator to produce a beat or difference frequency which, as stated, has the value  $F_x$ . The wave of this difference frequency appears as is well understood in the common anode branch containing the coil 12 to which the filter 13 is coupled. If the circuit contains sufficient amplification, the cycle of operations just described will continue indefinitely so long as the wave of frequency  $F$  continues to be applied, and as a result, the wave of frequency  $F_x$  will be continuously generated. Amplifiers may be introduced at other points in the circuit, if found desirable. If it is desired to use the frequency  $F_x$ , a

portion of the output wave of the amplifier A may be conducted through the circuit 19 and suitable filter or filters such as 20 leading to desired work circuits. If it is desired to use harmonics of the base frequency  $F_x$  these may be derived from the harmonic supply circuit HS through the selective circuits such as  $F'$ ,  $F''$ ,  $F'''$ , as shown. Two forms of selective circuits have been shown for this purpose, a band filter for the frequency  $F'$  and simple resonant circuits for the other frequencies. But these circuits may, of course, be all of the same type and of any suitable design.

No definite reason can be stated to account in detail for the starting of this sub-multiple generating circuit into operation, but it is thought that the starting may be explained in somewhat the same manner as in the case of the well-known vacuum tube oscillator. Given a sufficient amount of amplification and circuits having definite resonating properties, it would appear that an initial disturbance of very slight amount would rapidly build up into a sustained oscillation when the wave of frequency  $F$  is applied to the modulator. But whatever be the precise reason, the circuit, as above described, is found to operate in the manner indicated.

The reason that low-pass filters are sufficient at 13 and 16 may be seen from considering that so long as  $F_x$  and  $F_y$  are lower than  $F$ , no difference frequency will be produced within the transmission range of the filter 13 except the filter 16 transmit a sufficiently high frequency. But if the filter 16 should transmit a frequency higher than the requisite frequency, a frequency lower than  $F_x$  and therefore within the transmission range of the filter 13 would be produced. The requirement is, therefore, that the filter 16 pass a sufficiently high frequency, otherwise the circuit is inoperative, but that it should not pass too high a frequency, otherwise undesired low frequencies are produced, the effect of which would be at least to reduce the efficiency of the circuit and perhaps make the circuit tend to produce in largest amount frequencies that are not wanted at all. A low pass filter at 16 meet these requirements. If low frequencies are present in filter 16 these place a needless load on the modulator. This latter effect can be avoided by the use of a narrow band filter at 16, the filter 16 in the present instance being illustrated as such a filter. It is evident that a narrow band filter at 13 might also be used. However, the low pass filters in these two positions are operative as described and may be used if desired.

Reference will now be had to Figs. 1 and 2 which, if placed side by side, show diagrammatically a sending station and a portion of a receiving station for a multiplex carrier transmission system. The system, as illustrated, is a composite carrier telephone and

carrier telegraph system, the carrier telegraph channels employing frequencies within a definite range which is lower than the range employed by the telephone channels. The line ML is shown terminating in Fig. 1 in the composite filters  $HP_1$ ,  $HP_2$  and  $LP_2$  and in Fig. 2 in similar composite filters  $HP_4$ ,  $HP_5$  and  $LP_5$ . The line ML is assumed to be composited also for ordinary telephone transmissions employing frequencies lower than any of the carrier channels. The telephone currents are taken on and off from the line ML through the filters  $LP_1$  and  $LP_4$  which may lead to ordinary telephone line terminals. The filters  $HP_1$  and  $HP_4$  are designed to transmit currents having frequencies higher than the telephone frequencies, the transmitted frequencies including those employed by both the carrier telegraph and carrier telephone channels. The filters  $LP_2$  and  $LP_5$  transmit selectively all of the frequencies employed by the carrier telegraph channels and the filters  $HP_2$  and  $HP_5$  transmit the frequencies employed by all of the carrier telephone channels.

Referring first to the carrier telegraph side of the system, the filter  $LP_2$  is connected in the branch TG which is a two-way branch for the carrier telegraph transmissions. The branch TG is connected to the transmitting terminal circuit TT on one side and through the grouping filter GF to the receiving terminal RT on the other side. A number of transmitters  $T_1$ ,  $T_2$ ,  $T_3$  are indicated connected to the common terminal TT each of which transmitters is assumed to employ current of a different frequency. Similarly, selective receiving branches  $R_1$ ,  $R_2$  and  $R_3$  are indicated. Similar telegraph transmitting-receiving circuits (not shown) may be assumed to be associated with the branch containing the filter  $LP_5$  of Fig. 2.

The carrier telephone side of the system is connected to the branch TP containing the filter  $HP_2$ . The branch TP is a two-way transmission circuit and is provided with a transmitting loop TL containing the filter  $HP_3$  and a receiving loop RL containing the filter  $LP_3$ , it being assumed that all of the telephone channels transmitting from the station in Fig. 1 employ frequencies lying in a group of frequencies higher than the group used for receiving by these stations.

A number of low frequency lines  $LL_1$ ,  $LL_2$  and  $LL_3$  are indicated, these being assumed to be ordinary telephone lines, each of which is provided for two-way repeating with one of the carrier telephone channels. The line  $LL_1$ , for example, is provided with a balancing network N and a divided winding repeating coil 25 for enabling independent transmission from the line  $LL_1$  through the voice filter  $LF_1$  to the modulator  $M_1$  and transmission from the detector  $D_1$  through the voice filter  $LF_2$  to the line  $LL_1$ . Similar

connections correspondingly designated are used for the lines  $LL_2$  and  $LL_3$  and, of course, it will be obvious to connect other lines and to supply corresponding other channels as may be desired.

The carrier frequencies which are used for transmission by the various carrier telephone channels are derived as harmonic frequencies from a wave of base frequency, generated by the base frequency generator  $GF_0$ , which may be any suitable type of generator of sustained waves. For this purpose, a harmonic generator HG, which may be of the same type as the harmonic generator HG of Fig. 3, is connected to the source  $GF_0$ , preferably through an amplifier  $A_1$  and as a result of the well-known action of a harmonic generator, various harmonic or multiple frequencies are produced in the harmonic supply circuit  $HS_1$ . The system is assumed to be of the type in which no unmodulated component of the carrier frequency is transmitted to the line and accordingly in order to receive the signals transmitted through the system, it is necessary to supply a wave of the carrier frequency to the detecting circuits. A system of this general type is more fully described in British Patent No. 131,426. The harmonic supply branch  $HS_1$  is tapped at various points to the various channel apparatus. For example, one of the harmonics which will be referred to as the first, meaning the lowest one that is actually used, but which may be the first harmonic of the base frequency or any other desired harmonic, is transmitted through the filter  $1F_2$  to the detector  $D_3$ , the next higher or second harmonic being utilized for reception by the second channel and being applied to the detector  $D_2$  through the filter  $2F_2$ , the next higher or third harmonic being applied through the filter  $3F_2$  to the detector  $D_1$ . If other channels were employed the succeeding higher harmonics would be used for reception by other channels but on the basis of a three-channel system as being described, the fourth highest of the multiple frequencies will be used for transmission by the lowermost channel in the drawing and will be transmitted through the filter  $4F_2$  to the modulator  $M_3$ , the similar filters  $5F_2$  and  $6F_2$  supplying the modulators of the other channels with succeeding higher harmonics. The detectors or demodulators of the several channels which may be of the type or types disclosed in United States Patent to Carson, 1,343,306, issued June 15, 1920, are connected through channel filters  $1F_1$ ,  $2F_1$ ,  $3F_1$  to the receiving loop RL and similarly, the modulators, also disclosed in the above-identified patent to Carson, are connected to the transmitting loop TL through channel filters  $4F_1$ ,  $5F_1$  and  $6F_1$ . A filter  $7F_1$ , transmitting preferably a frequency higher than any of harmonics used by the channels is connected between the harmonic generator HG and the transmitting

loop TL. The purpose of this higher harmonic, which is unmodulated by any of the signals, will appear later on.

The operation of so much of the system as has been described will be clear from the above given description of the arrangement of the various elements. Voice waves received over the line  $LL_1$  are transmitted through the filter  $LF_1$  and impressed on the modulator  $M_1$  where they serve to control the transmission of a wave of the 6th multiple frequency derived from the harmonic supply circuit  $HS_1$ . The modulated wave as it leaves the modulator  $M_1$  comprises both side bands but substantially none of the unmodulated carrier component by virtue of the well-known action of the balanced arrangement of the modulator. The filter  $6F_1$  may be arranged to pass both of these side bands but is preferably designed to transmit only the upper side band. In a similar manner, voice waves received from the line  $LL_2$ , modulate a wave of the 5th multiple frequency which is selectively transmitted by the filter  $5F_1$  and speech waves received over the line  $LL_3$  modulate a wave of the 4th multiple frequency which is transmitted by the filter  $4F_1$ . All of these modulated waves together with the 7th multiple frequency from the filter  $7F_1$  are transmitted by the filter  $HP_3$ , the filter  $HP_2$ , and the filter  $HP_1$  to the line ML. None of the waves so transmitted passes through any of the filters  $LP_1$ ,  $LP_2$  or  $LP_3$  on account of their high attenuating properties for currents of the carrier telephone transmitting frequencies.

The carrier telephone transmissions which are being received at the station of Fig. 1 from the line ML pass selectively through the filters  $HP_1$ ,  $HP_2$ , and  $LP_3$  to the receiving loop RL from which the respective channel frequencies are passed selectively by the channel filters  $1F_1$ ,  $2F_1$ , and  $3F_1$  to the respective detectors or demodulators. In each of the detectors, the received waves interact with some of the carrier of that channel supplied from the circuit  $HS_1$  to produce speech waves which pass to the respective lines  $LL_1$ ,  $LL_2$ ,  $LL_3$  through the respective voice filters  $LF_2$ ,  $LF_3$ ,  $LF_4$ .

The terminal arrangements shown in Fig. 2 are arranged in two separate terminals or stations, the broken line S—S indicating that the low-pass filter  $LP_3$  which transmits the carrier telegraph channels as a group is positioned at a considerable distance from the carrier telephone receiving circuits. It may often be desired, in practice, to have the carrier telegraph channels and the carrier telephone channels terminate at different stations and the carrier wave control system of the invention is particularly suited to systems in which this occurs since the control wave is of a higher frequency than any of the carrier telegraph frequencies and lies within

the transmission range of the carrier telephone grouping or separating filters. It has heretofore been suggested to transmit a relatively low base frequency over the line such as the frequency of the source  $GF_0$  for example, and at a distant station to derive from the base frequency so transmitted, the various carrier frequencies used in reception of the signals. Since, however, the frequency of the wave from the source  $GF_0$  ordinarily lies in the transmission range of the carrier telegraph filters, it is impractical in such a system to terminate the carrier telegraph channels at a different point from the carrier telephone channels. The present invention, however, makes the carrier telegraph side of the system practically independent of the carrier telephone side and either side of the system may terminate in either end at separate points.

Only so much of the carrier telephone circuits have been shown in Fig. 2 as are deemed necessary to illustrate the application of the invention to a system in which the carrier waves may be generated from a frequency higher than the base frequency. It is to be noted that at the station shown in Fig. 2, the received carrier telephone frequencies are, as a group, higher than the transmitted frequencies from this station. The transmitting terminal circuit TL contains the filter  $LP_3$  which selectively transmits the outgoing carrier telephone frequencies and the receiving loop RL contains the filter  $HP_3$  for selectively passing the received carrier telephone frequencies. The receiving loop RL is assumed to lead to the various receiving channel filters in the same way that the receiving loop RL in Fig. 1 is associated with the receiving channels of that station. The filter  $7F_2$  is also connected to the loop RL, this filter being arranged to transmit selectively the same frequency as the filter  $7F_1$ . The filter  $7F_2$  leads to a sub-multiple generating circuit of the type shown in Fig. 3, the modulator being indicated at SM, the output of the modulator leading to a filter  $OF_1$  which selectively transmits a wave of the same frequency as the wave generated at  $GF_0$ , a harmonic generator  $HG_2$  leading to a harmonic supply circuit  $HS_2$ , which leads to the modulators and demodulators of the various channels in the same way that the circuit  $HS_1$  connects with the channel apparatus of Fig. 1. Also connected between the harmonic generator  $HG_2$  and the sub-multiple modulator SM are the filters  $6F_3$  and  $6F_4$  arranged each to pass selectively the 6th multiple frequency. Amplifiers A, A may be introduced at various points in the circuit as may be found desirable.

The operation of the harmonic reproducing circuits of Fig. 2 is substantially the same as that described of the arrangement of Fig. 3. The filter  $OF_1$  selects from the output of

the sub-multiple modulator SM a wave of the base frequency from which the harmonic generator  $HG_2$  produces a number of multiple or harmonic frequencies which are utilized by the various channel apparatus. The 6th multiple frequency is selectively transmitted through the filters  $6F_3$  and  $6F_4$  back to the input side of the sub-multiple modulator where it combines with the 7th multiple frequency received from the line and the interaction of these two waves continues to produce the base frequency wave.

In the drawings and in the descriptions thus far, a harmonic generator is assumed to be employed in the feed-back circuit of the sub-multiple modulator, between its output and its input sides. It is preferable to employ such a harmonic generator or other frequency converting device since by its use a greater number of frequencies can be derived and also there is greater choice as to the sub-multiple frequency to be obtained. It is evident, however, that a special case of the circuits above described would be that in which the harmonic generator is omitted and the sub-multiple frequency is one-half the frequency of the incoming wave. It may at times be desired to use this simple form of the invention and certain at least of the claims are intended to include such an arrangement.

A great many uses for the invention, other than those mentioned, will occur to those working in the electrical arts and certain modified arrangements may be desirable dependent upon the situations encountered in the various uses. No attempt has been made to indicate all of these variations. The circuits that have been disclosed should be regarded as typical, the scope of the invention being defined in the claims.

What is claimed is:

1. The method of generating a wave of required frequency from a single sinusoidal wave of a given different frequency comprising maintaining a sustained cycle of wave-modifying operations including modulation of the wave of given frequency by a wave, driving the last mentioned wave as a product of such modulation, and deriving the wave of required frequency solely as a product of such modulation.

2. The method of deriving a wave of required frequency from a single sinusoidal wave of a given different frequency comprising applying the wave of given frequency to a modulator, reapplying a wave derived from the output components of said modulator to the input side of said modulator and deriving said wave of required frequency solely from the modulation components resulting from modulation of the wave of given frequency by said reapplied wave.

3. The method of deriving a wave of required frequency from a single sinusoidal

wave of a given different frequency comprising continuously applying said wave of given frequency to a wave-modifying circuit and reapplying to said circuit through a frequency-changing device, a wave component produced in said wave-modifying circuit solely by interaction of the wave of given frequency with the reapplied wave component.

4. The method of deriving a wave of required frequency from a single sinusoidal wave of a given different frequency comprising continuously modulating said wave of given frequency by a second wave different therefrom in frequency by the frequency of the required wave, deriving said second wave as a result of such modulation, and deriving said required wave solely as a result of such modulation.

5. The method of producing a required wave bearing a definite frequency relation to a single sinusoidal wave of a given frequency comprising providing a self-sustained cycle of wave-modifying operations including modulating the given wave to produce wave components, using one of said components to control said modulating of the given wave and deriving the required wave from one of said wave components.

6. The method of deriving a wave of required frequency from a single sinusoidal wave of given frequency which comprises impressing the wave of given frequency on a modulator, feeding back from the output side to the input side of the modulator a wave of such a frequency that the modulation components resulting from the interaction of the said two applied waves contain a wave of the required frequency, and selecting out the wave of required frequency.

7. The method of producing a wave of required frequency from a single sinusoidal wave of given frequency which comprises continuously carrying out a closed cycle of operations including obtaining said required wave solely by modulation of the wave of given frequency by another wave, and deriving said other wave as a result of said modulation.

8. Means to generate a wave of definite frequency under control of a single sinusoidal wave of a given different frequency comprising a modulator, means to apply the given wave to the input side of said modulator, a circuit for feeding back to the input side of said modulator a wave derived from the output side of said modulator and a circuit for deriving the said wave of definite frequency solely as a modulation product of said two waves from the output side of said modulator.

9. In combination, a modulator, a circuit for applying to said modulator one continuous sinusoidal wave, a circuit for feeding back to the input side of said modulator some of the modulated output wave of said modula-

tor, said modulator operating to produce solely from said two waves a wave of a definite desired frequency and a circuit associated with the output side of said modulator  
 5 for selecting said wave of definite desired frequency.

10. A wave generator comprising a wave-modifying circuit, means to apply to said circuit one sinusoidal wave of given sustained frequency and another wave, said  
 10 wave-modifying circuit operating to produce components representing the combination frequencies of the applied waves, one of said components being the wave which it is desired to generate, means to derive said other  
 15 wave solely from a modulation component produced by said wave-modifying circuit and means to select the desired generated wave.

11. A regenerative circuit including a  
 20 modulator having input and output circuits, the input circuit being provided with a source for a sinusoidal supply of sustained wave of a definite frequency, a feed-back circuit for returning from the output to the input of  
 25 said modulator a wave of a frequency different from said definite frequency of said sustained wave, said modulator serving to produce from said two waves the wave that is fed back, said circuit being provided with sufficient amplification to maintain the regenerative action.

12. A regenerative circuit including a modulator provided with a source for a sustained sinusoidal wave of a definite frequency, a selective circuit connected to the  
 35 output side of said modulator and selective of a frequency lower than said definite frequency, means to derive from said wave of lower frequency a wave differing in frequency from the frequency of said sustained  
 40 wave by the frequency of the wave transmitted by said selective circuit, and means to apply the derived wave to the input side of said modulator, said modulator operating to produce solely from the applied waves a wave of the frequency to be transmitted by said selective circuit.

13. A regenerative circuit comprising a modulator provided with a source for a sustained sinusoidal wave and with a feed-back circuit for returning from the output side to the input side of the modulator a wave of a frequency different from the frequency of said source but definitely related thereto  
 55 combine in the modulator with the wave from said source, and frequency selective elements in said feed-back circuit arranged to control the feeding back of a wave of such a frequency that the wave resulting from the combining of the wave from the source and the wave so fed back is the wave of the frequency that is desired to be generated.

14. A regenerative circuit comprising a modulator provided with a source for a sustained sinusoidal wave of a definite frequency,

a filter connected to the output side of said modulator and designed to pass a wave of a frequency different from the frequency of said source, a frequency-changing device connected to the output side of said filter, and  
 70 a second filter connected between the frequency-changing device and the input side of said modulator, said second filter arranged to derive from said device and to apply to said modulator a wave of a frequency differing  
 75 from the frequency of the said source by the frequency of the wave passed by said first-mentioned filter, said circuits containing sufficient amplification to maintain the regenerative action.

15. In a carrier wave signaling system, a sending station, a receiving station, a source of waves of definite frequency at the sending station, circuits for deriving waves of other frequencies from the wave from said source  
 85 and for controlling each such derived wave in accordance with signals to be transmitted, means to derive from the wave from said source a single sinusoidal control wave having a frequency different from any of said other  
 90 waves, said waves so derived and so controlled being transmitted to the receiving station, circuits for receiving said control wave and for deriving therefrom other waves corresponding in frequency to the said waves of  
 95 other frequencies derived at said sending station, and means to utilize the waves derived at the receiving station in receiving said signals.

16. In a carrier wave signaling system, a sending and receiving stations, a source of sinusoidal waves of base frequency at the sending station, circuits for deriving sinusoidal harmonic frequency waves from said wave of base frequency and for transmitting said  
 105 waves of harmonic frequencies, means at a receiving station to receive selectively one of said harmonic frequency sinusoidal waves and a regenerating circuit for deriving solely from said received wave a wave of the said  
 110 base frequency.

17. In a carrier wave signaling system, a sending and a receiving station, a source of waves of base frequency at the sending station, means to derive  $n$  sinusoidal waves of  
 115 as many frequency multiples of said base frequency and to control each of the  $n$  waves by signals to be transmitted, means to derive and transmit the  $(n+1)$ th sinusoidal frequency multiple wave, means at the receiving station  
 120 for receiving each of the transmitted waves, a modulator to which the  $(n+1)$ th frequency multiple wave is applied, a filter of the base frequency connected to the output side of said modulator, a harmonic generator connected  
 125 to said filter and arranged to generate waves of multiple frequencies from the wave passed by said filter and a second filter for returning the  $n$ th multiple frequency wave from said harmonic generator to said modulator to com- 130

bine with the  $(n+1)$ th multiple frequency to produce a wave of base frequency for said harmonic generator, circuits also being provided for deriving from said harmonic generator waves of  $n$  frequency multiples corresponding respectively to the  $n$  waves transmitted from the sending station and for utilizing these waves in receiving said signals.

18. In a composite carrier telephone and carrier telegraph system, a line, stations thereon, carrier telegraph channels employing frequencies comprised in a lower range, carrier telephone channels employing frequencies comprised in a higher range, means at a sending station for deriving the carrier waves utilized by the several carrier telephone channels as frequency multiples of a base frequency wave, said carrier telegraph channels terminating at a different station on said line from said carrier telephone channels, means to transmit between the carrier telephone terminals a control sinusoidal wave of a frequency above the carrier telegraph range and above said base frequency, and means at a receiving station for deriving solely from said control wave a series of waves of the frequencies of the several carrier telephone carrier waves.

19. In a wave transmission system, means to transmit a single sinusoidal wave of a single definite frequency, means to receive said wave of said single frequency, and means to derive under control of said wave other waves bearing a definite frequency relation to the transmitted wave, some of said derived waves having frequencies lower than that of the transmitted wave.

20. In a wave transmission system, means to transmit a single sinusoidal wave of a single definite frequency, means to receive said wave of said single frequency, and means including selective circuits and wave distorting means for deriving solely from the received wave a wave of a lower frequency definitely related to the frequency of the received wave.

21. A wave generator comprising a modulator, a selective circuit, a frequency changer and a selective circuit arranged serially in a closed cycle, a source for a sinusoidal wave of a given frequency coupled to said modulator, and outgoing selective circuits coupled to said frequency changer, said given frequency of said source of waves being equal to the sum of the frequencies of said two first mentioned selective circuits.

22. The method of wave generation which comprises carrying out a self-sustained cycle of operations including continuously modifying a single sinusoidal wave of given frequency by a frequency solely derived from said wave, and deriving in the modifying operations said frequency derivative of said wave of given frequency.

23. The method of wave generation which comprises carrying out a self-sustained cycle

of operations including continuously modulating a single sinusoidal wave of given frequency by another wave, and producing derivatives solely from said wave of given frequency including the modulating wave.

24. A wave generating circuit for producing waves of a plurality of frequencies solely from a sinusoidal wave of given frequency, some at least of said plurality of frequencies being lower than said given frequency comprising a source of waves of the given frequency, a modulator coupled thereto, a harmonic generator connected with the output of said modulator, and a plurality of selective circuits connected to the output side of said harmonic generator, one of said selective circuits leading to the input side of said modulator, and the others of said selective circuits being respectively selective of the individual frequencies of said plurality of frequencies.

25. In a wave transmission system comprising a transmitting and a receiving station, the method of reproducing at said receiving station a wave of a certain relatively low frequency which matches the frequency of a wave generated at the transmitting station, which method consists in generating at the transmitting station a single sinusoidal wave of a single frequency higher than and definitely related to the first-mentioned frequency, transmitting said higher frequency current to said receiving station, and deriving solely from the transmitted wave a wave of said first-mentioned frequency.

26. In a wave transmission system comprising a transmitting and a receiving station, the method of reproducing at the receiving station a certain wave of relatively low frequency which matches the frequency of a wave generated at said transmitting station, which method consists in transmitting a single sinusoidal wave harmonically related in frequency to the first-mentioned wave from said transmitting station to said receiving station, and solely deriving at the receiving station from said wave of harmonic frequency said wave of relatively low frequency.

27. In a wave transmission system comprising a transmitting and a receiving station, the method of reproducing at the receiving station a certain wave of relatively low frequency which matches the frequency of a wave generated at the transmitting station, which method consists in generating at the transmitting station a single sinusoidal wave of higher frequency and definitely related in phase and frequency to said wave of relatively low frequency, transmitting said high frequency wave to said receiving station, and at said receiving station deriving a wave of said relatively low frequency solely from the transmitted wave.

28. In a transmission system having a transmitting and a receiving station, a line,

means at said transmitting station to generate a wave of relatively low frequency, means at said transmitting station for generating a sinusoidal wave harmonically related to said low frequency wave, means for transmitting the harmonic wave over said line to said receiving station, and means at said receiving station to reproduce solely from the transmitted sinusoidal harmonic wave a wave of said relatively low frequency. 10

In witness whereof, I hereunto subscribe my name this 15th day of March, A. D. 1922.

JOSEPH W. HORTON.