

March 31, 1942.

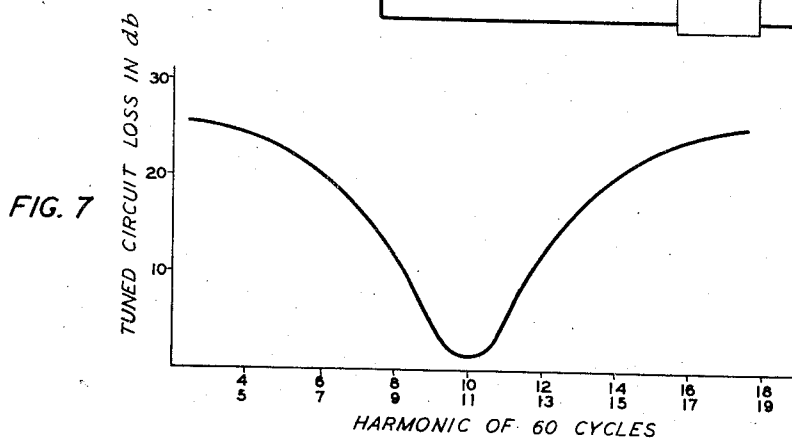
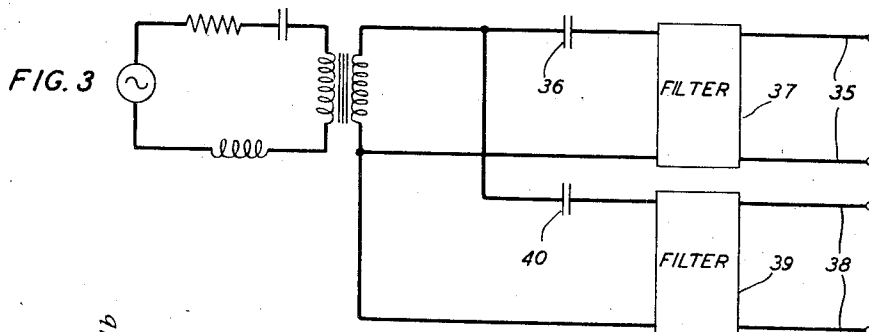
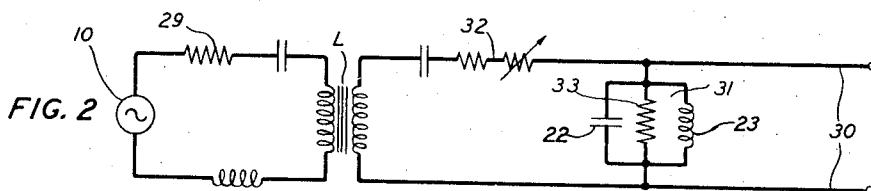
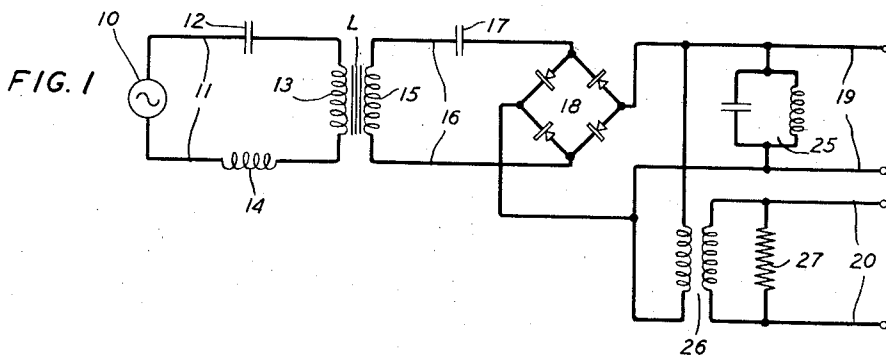
L. R. WRATHALL

2,277,809

SIGNALING WAVE GENERATOR

Filed March 30, 1940

2 Sheets-Sheet 1



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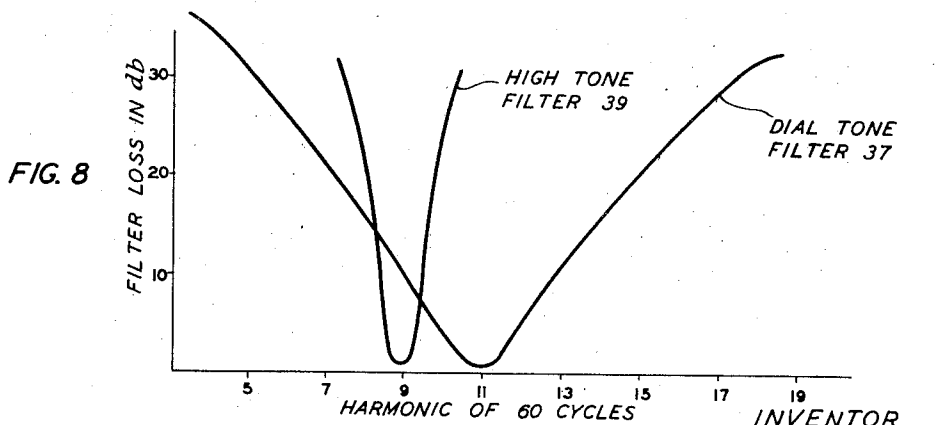
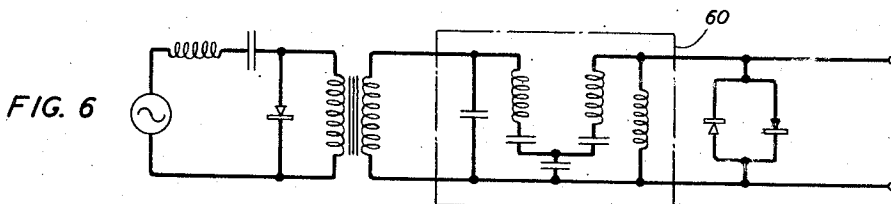
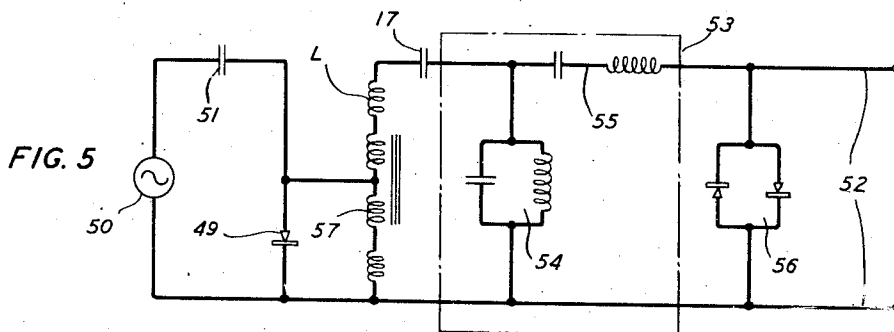
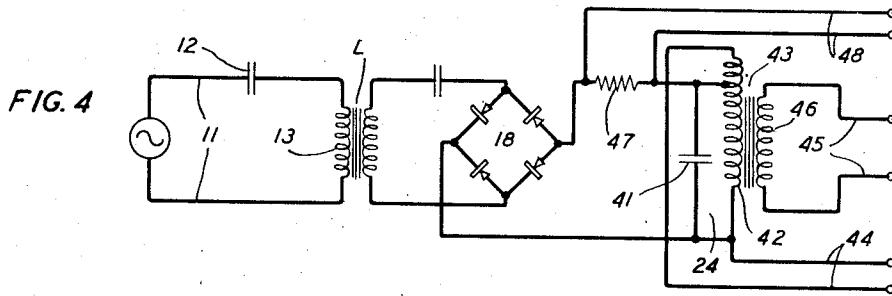
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SIGNALING WAVE GENERATOR

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2 Sheets-Sheet 2



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2,277,809

SIGNALING WAVE GENERATOR

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Application March 30, 1940, Serial No. 326,908

12 Claims. (Cl. 172-281)

This invention relates to the generation of alternating current signaling waves, and more particularly to apparatus for generating such waves for use as signaling tones for telephone systems.

Modern telephone systems require for signaling purposes a relatively large number of tones which are either pure sine waves or complex waves. An analysis of "high" tone, for example, will show that it is substantially a sine wave having a frequency of the order of 500 cycles and an analysis of dial and busy tones will show that both are complex waves comprising essentially a modulated wave having a carrier frequency of the order of 600 cycles and side-bands separated therefrom by even multiples of 60 cycles. In the case of 20-cycle ringing between repeaters it is necessary to avoid cut-off, which is usually below 200 cycles, by modulating a 20-cycle wave on a 1000-cycle wave as such modulated wave is passed through the repeater. Heretofore, the waves for these tones have been provided by vibrators or rotating generators depending on the capacity of a telephone central office. Such tone equipment requires constant care to maintain reliable and efficient operation of the telephone system. Consequently, it is desirable to eliminate or reduce as much as possible the need for such care while maintaining adequate and economical performance.

Accordingly, this invention contemplates a generation of certain telephone signaling waves by means of apparatus embodying no moving parts.

The main object of the invention is to provide apparatus for expeditiously generating signaling waves for telephone systems.

Another object is to increase the simplicity, economy and reliability of such apparatus.

A further object is to minimize the care required to supervise such apparatus.

Still another object is to provide such apparatus without moving parts.

Still another object is to provide flexibility in such apparatus to enable operation from various power sources.

Heretofore, harmonics of a fundamental alternating current wave have been produced by apparatus comprising a source of fundamental waves and a saturable magnetic-core coil applied thereacross. Connecting such coil to an output circuit including a capacity causes a desired group of harmonics to be produced with uniformly large amplitudes extending over the entire group

in the manner pointed out in my Patent No. 2,117,752, granted May 17, 1938.

In accordance with one embodiment, the invention comprises a frequency-selective network interposed in the output circuit and proportioned with an impedance frequency characteristic to attenuate the amplitudes of the produced group of harmonics such that the attenuated harmonics simulate substantially a modulated carrier wave comprising a carrier wave having a frequency equivalent to the frequency of a certain harmonic and side-bands having frequencies equivalent to the frequencies of other harmonics.

A feature of the invention is the production of dial and busy signaling waves comprising certain even harmonics. Another feature is the production of dial and busy signaling waves comprising certain odd harmonics. Additional features are a control of the level of the dial and busy signaling waves, and the production of both odd and even harmonics in the saturable magnetic-core coil.

The invention will be readily understood from the following description taken together with the accompanying drawings in which:

Fig. 1 is a schematic circuit showing one embodiment of the invention;

Fig. 2 is a schematic circuit illustrating another embodiment of the invention;

Fig. 3 is a modification of Fig. 2;

Fig. 4 is a modification of Fig. 1;

Fig. 5 is still another embodiment of the invention;

Fig. 6 is a modification of Fig. 5;

Fig. 7 represents action in Figs. 1, 2 and 4; and Fig. 8 represents action in Figs. 3, 5 and 6.

In the following description the same reference numerals are employed to designate identical elements appearing throughout the several figures.

Referring to Fig. 1, a source 10 of fundamental alternating current waves, preferably 60 cycles, is applied to a primary circuit 11 comprising in series capacity 12, winding 13 of a non-linear magnetic-core coil L and inductance 14. The capacity 12 and inductance 14 constitute a series resonant circuit for tuning the primary circuit 11 to the fundamental wave so that the latter may follow substantially a sine wave form. Coupled to the primary circuit 11 is a secondary or output circuit 16 comprising in series winding 15 of the coil L, capacity 17 and a copper-oxide bridge 18 across the horizontal diagonal of which are output branches 19 and 20. Such circuit or-

ganization effects uniformly large amplitudes in a desired group of even harmonics of the fundamental wave in the manner pointed out in my patent, supra.

In accordance with the invention, a parallel tuned circuit 25 disposed in bridge of the output branch 19 is proportioned with an impedance frequency characteristic to attenuate the amplitudes of the desired group of even harmonics appearing across the terminals of the branch 19 such that a certain harmonic possesses substantially the amplitude with which it was initially produced and the even harmonics adjacent thereto possess progressively decreasing amplitudes as the harmonic order decreases and increases relative to the order of the certain harmonic. In other words, the tuned circuit 25 is antiresonant to the certain harmonic and passes harmonics adjacent thereto with predeterminedly varying amounts of attenuation. The attenuated harmonics available at the output terminals of the branch 19 simulate substantially a modulated carrier wave comprising a carrier wave having a frequency corresponding to the frequency of the certain harmonic and upper and lower sidebands separated therefrom by frequency bands equivalent to the second harmonic of the fundamental wave and multiples thereof. Thus, the frequencies of the upper and lower sidebands correspond to the frequencies of other harmonics.

The predetermined attenuation of certain even harmonics is shown in upper abscissa-scale of Fig. 7. For the purpose of this illustration, the carrier wave corresponds to the 10th harmonic and the respective lower and upper sidebands correspond to the 8th, 6th and 4th and the 12th, 14th and 16th harmonics. Thus, for a 60-cycle fundamental wave, the carrier wave is 600 cycles, the lower sidebands are 480, 360 and 240 cycles and the upper sidebands 720, 840 and 960 cycles. Harmonics attenuated in the above manner provide a complex wave which is suitable for translation into dial tone in telephone systems by use, for example, of the familiar telephone receiver, not shown. An outstanding feature of this tone is that it contains no 60-cycle or fundamental wave component. Independent windings 13 and 15 of the coil L serve to isolate electrically the source of 60-cycle fundamental waves from the harmonic waves in the output branch 19.

Busy tone waves, which are interrupted dial tone waves, are available at the terminals of the output 20 which is applied across the secondary winding of a transformer 26 whose primary winding shunts the output branch 19. Thus, busy-tone waves whose harmonic composition and attenuation are identical with those of the dial-tone waves are supplied from the output branch 20 to an interrupter, not shown, to be made useful as busy-tone signal in a telephone system. A resistance 27, preferably about 25 ohms, disposed in bridge of the branch 20 serves to prevent undue reaction on the dial-tone waves in the branch 19 during the interval when the busy-tone waves in branch 20 are being subjected to the action of the interrupter. Such avoided reaction may embrace either a repetition of the interruptions in the dial-tone waves or a variation in the voltage thereof.

Fig. 2 is an arrangement for producing dial tone waves comprising certain odd harmonics which are initially produced with uniformly large amplitudes in accordance with my patent, supra. Resistances 29 and 32 prevent singing around a

low impedance path including the coil L and fundamental source 10. Resistance 33 in shunt of output circuit 30 serves to adjust the impedance of the harmonic generating circuit looking back from the terminals of the output circuit 30. In accordance with the invention, a parallel tuned circuit 31 embodying capacity 22 and inductance 23 in bridge of the output circuit 30 is proportioned with an impedance frequency characteristic to attenuate the amplitudes of the produced group of odd harmonics similarly to the tuned circuit 25 in Fig. 1, except that tuned circuit 31 functions with respect to odd harmonics.

The attenuation of certain odd harmonics by the circuit 31 to simulate substantially a modulated carrier wave is shown in the lower abscissa-scale of Fig. 7. For the purpose of this illustration, a carrier wave corresponding to the 11th harmonic is provided in the output circuit 30 substantially with its original amplitude and the respective lower and upper sidebands corresponding to the 9th, 7th and 5th and the 13th, 15th and 17th harmonics are provided with progressively decreasing amplitudes as the harmonic order decreases and increases relative to the 11th harmonic. Thus, for a 60-cycle fundamental wave, the carrier wave is 660 cycles and the respective lower sidebands are 540, 420 and 300 cycles and the upper sidebands 780, 900 and 1020 cycles. Dial tone waves comprising odd harmonics are useful in telephone systems in which the presence of a relatively large 60-cycle component is unobjectionable.

Fig. 3 is a modification of Fig. 2 for producing dial tone waves comprising certain odd harmonics and a high tone wave comprising a pure sine wave, both of which tone waves are simultaneously obtained from the produced group of harmonics. Disposed in the output branch 35 is a capacity 36 in series with a filter 37 and in the bridging output branch 38 a capacity 40 in series with a filter 39. The operation of Fig. 3 is substantially identical with that of Fig. 2.

In accordance with the invention, filter 37 is proportioned with an impedance frequency characteristic to attenuate the amplitudes of the produced group of odd harmonics as shown in Fig. 8. Accordingly, the odd harmonic composition and attenuation thereof to provide dial tone waves are identical with those shown in Fig. 2 and described above in connection therewith, except in the respect that the characteristic in Fig. 8 is slightly sharper than that in Fig. 7. The objectionable 60-cycle component pointed out above with respect to Fig. 2 may be obviated or substantially reduced by a proper design of the filter 37.

Filter 39 providing a high-tone wave supply across the terminals of output branch 38 is proportioned with an impedance frequency characteristic to attenuate the amplitudes of certain odd harmonics as illustrated in Fig. 8. Accordingly, the 9th harmonic corresponding to a frequency of 540 cycles is passed substantially with the original amplitude while the adjacent harmonics have their amplitudes substantially entirely attenuated. Thus, a high tone wave is essentially a pure sine wave having a frequency of 540 cycles.

Fig. 3 embodies capacities 36 and 40 individual to the respective output branches 35 and 38 to control (a) the power levels of the dial and high tone waves and (b) the impedances of the respective branches such that each branch has relatively high impedance outside of the pass band

of the filter connected therein for waves to be selected by the filter in the other branch.

Fig. 4, which is a modification of Fig. 1, produces both dial and busy tone waves. Capacity 12 and winding 13 of the non-linear magnetic-core coil L serve to tune the primary circuit 11 to the 60-cycle fundamental wave. The circuit organization, as in Fig. 1, effects uniformly large amplitudes in a desired group of even harmonics of the fundamental wave. In accordance with the invention, parallel tuned circuit 24 comprising capacity 41 and a portion of primary winding 42 of output transformer 43 and disposed in bridge of output circuit 44 is proportioned with an impedance frequency characteristic to attenuate the amplitudes of the produced group of even harmonics in the manner illustrated in Fig. 7 and described above in connection with Fig. 2.

Accordingly, dial tone waves comprising predeterminedly attenuated harmonics are supplied across the terminals of the output circuit 44. At the output circuit 45 which is applied across secondary winding 46 of the output transformer 43 are available busy-tone waves whose harmonic composition and attenuation are identical with those of the dial-tone waves. The impedance of the secondary winding 46 is adjusted such that during the interruptions of the busy-tone waves, that is, during no load and full load across the terminals of the output 45 there is substantially no change in the dial-tone wave voltage across the terminals 44, 44.

A resistance 47 embodied in series in the harmonic output circuit serves (a) to control the flow of direct current in the output circuit thereby enabling a use of relatively small copper-oxide elements in the non-linear bridge 18, (b) to adjust the impedance of the harmonic output circuit to increase the effectiveness of the tuned circuit 24 which in turn may be reduced in size from a physical standpoint, and (c) to provide a source of direct-current voltage which may be utilized to control the operation of a direct-current relay, not shown, to cut in a stand-by source of fundamental waves in case of a failure in the commercial supply thereof. This voltage may be taken off at the terminals of output circuit 48.

Fig. 5 produces both odd and even harmonics of a fundamental wave and accordingly combines in a single circuit, the arrangements of Figs. 1 and 2, except the copper-oxide bridge of Fig. 1 is eliminated. Referring to Fig. 5, a source 50 of fundamental alternating-current waves, preferably 20 cycles, is applied through a capacity 51 to input winding 57 of the coil L whose output circuit is substantially identical with that shown in Fig. 2 except in the respect that will be hereinafter mentioned.

In accordance with this modification, a copper-oxide element 49 connected in shunt of the input winding 57 of the coil L functions (a) to provide a direct-current bias therefor and (b) to apply input of one polarity of the fundamental wave to the non-linear magnetic-core coil and to reduce at the same time to a relatively small amount the input of the opposite polarity of the fundamental wave thereto. The simultaneous accomplishment of these functions tends to produce a desired group of both odd and even harmonics at the output circuit 52. Otherwise, the organization of Fig. 5 is such as to effect uniformly large amplitudes in the produced group of odd and even harmonics in the manner pointed out in my patent, supra.

The output of the coil L embodies a band-pass

filter 53 comprising a parallel-tuned circuit 54 disposed in bridge of the output circuit 52 and a series-tuned circuit 55 connected in series therein. In accordance with the invention, the filter 53 is proportioned with an impedance frequency characteristic to attenuate the amplitudes of the produced group of odd and even harmonics such that a certain harmonic is passed substantially with its original amplitude and harmonics adjacent immediately to the certain harmonic are passed with their amplitudes attenuated substantially 6 decibels while other adjacent harmonics are passed with their amplitudes attenuated in progressively increasing amounts. In other words, the filter 53 possesses an attenuation characteristic which is substantially identical with that of dial-tone filter 37 shown in Fig. 8 and described above in connection with Fig. 3 except, as a 20-cycle fundamental wave is employed, the 50th harmonic is the certain harmonic passed with the original amplitude and the 49th and 51st harmonics have their amplitudes attenuated substantially 6 decibels while the next adjacent harmonics, namely, the 47th, 45th, etc. and 53rd, 55th, etc. have their amplitudes attenuated progressively in increasing amounts as the harmonic order increases and decreases relative to the 50th harmonic.

Accordingly, the filter 53 passes approximately with no attenuation a 1000-cycle wave and attenuates substantially 6 decibels the 980 and 1020-cycle waves and attenuates in progressively increasing amounts the 960, 940, 920, etc., and 1040, 1060, 1080, etc., cycle waves. Thus, the attenuated harmonics in the output circuit 52 simulate substantially a modulated carrier wave comprising a carrier wave having a frequency corresponding to 1000 cycles and lower and upper side-bands having frequencies corresponding to the respective 980, 960, 940, 920, etc., and 1020, 1040, 1060, 1080, etc., cycles. In other words, the 1000-cycle carrier wave has side-bands separated therefrom by frequency bands equivalent to the fundamental frequency and multiples thereof. Oppositely poled copper-oxide elements 56 control the level of the harmonic voltage available at the terminals of the output circuit 52.

Such simulated modulated carrier wave is useful in signaling between telephone repeaters of which a plurality are usually embodied in a telephone system extending between two remote geographical points. Ordinarily, ringing therebetween involves a 20-cycle wave but due to the cut-off of repeaters, which cut-off is below 200 cycles, it has been found expedient to modulate a 1000-cycle wave with a 20-cycle wave as such modulated wave is readily passed by the repeaters. At the repeater where 20-cycle ringing is required, the simulated modulated carrier wave is demodulated to provide the 20-cycle ringing wave.

Fig. 6, which is a modification of Fig. 5, also produces both odd and even harmonics of a fundamental alternating-current wave, except capacity 17 of Fig. 5 is omitted. This is possible because output filter 60 looks like a capacity outside of its pass band. Otherwise, the operation of Fig. 6 is identical with that of Fig. 5. It is to be understood that the attenuation characteristics of both filters 53 and 60 may be adjusted to meet individual circuit requirements.

Obviously, the frequency-selective networks may in certain cases be proportioned with impedance frequency characteristics that are opposite to those illustrated in Figs. 7 and 8 and

described above in connection therewith, that is, impedance frequency characteristics which have high loss for a certain harmonic and progressively decreasing amounts of loss for harmonics adjacent thereto. Such attenuated harmonics may also simulate modulated carrier waves in the manner mentioned hereinbefore.

While the invention is described particularly with respect to a saturable magnetic-core coil, it is to be understood that it is not necessarily limited thereto as it may be readily practised in connection with harmonic producers embodying gas tubes, thyrte or other non-linear devices.

What is claimed is:

1. A wave generator comprising in combination a source of fundamental alternating-current waves, means including a saturable magnetic-core coil applied across said source to produce a desired range of harmonics, an output circuit for said harmonic producing means, and means comprising a frequency-selective network interposed in said output circuit and proportioned with an attenuation frequency characteristic to attenuate the amplitudes of said harmonics such that the attenuated harmonics in said output circuit simulate substantially a modulated carrier wave comprising a carrier wave having a frequency corresponding to the frequency of a certain harmonic and side-bands having frequencies corresponding to the frequencies of other harmonics.

2. The wave generator according to claim 1 in which said output circuit includes an effective capacity so that the harmonics are produced with uniformly large amplitudes extending over the entire range and the network attenuates the amplitudes of said harmonics such that a certain harmonic possesses the original amplitude and other harmonics possess progressively decreasing amplitudes as their harmonic order decreases and increases with respect to the harmonic order of said certain harmonic.

3. A wave generator comprising in combination a source of fundamental alternating-current waves, means including a saturable magnetic-core coil applied across said fundamental source to produce a range of harmonics, an output circuit including an effective capacity so that said harmonics are produced with uniformly large amplitudes extending over the entire range, and means comprising a frequency-selective network interposed in said output circuit and proportioned with an attenuation frequency characteristic to attenuate the amplitudes of said harmonics such that a certain harmonic possesses substantially the original amplitude and adjacent harmonics possess progressively decreasing amplitudes as their harmonic order decreases and increases with respect to the harmonic order of said certain harmonic, the attenuated harmonics simulating substantially a modulated carrier wave comprising a carrier wave having a frequency corresponding to the frequency of said certain harmonic and side-bands having frequencies separated therefrom by a band equivalent to the frequency of the fundamental wave and multiples thereof.

4. A signaling wave generator comprising in combination a source of fundamental alternating-current waves, means including a saturable magnetic-core coil applied across said source to produce a range of even harmonics, an output circuit for said harmonic producing means, and means comprising a frequency-selective means interposed in said output circuit and propor-

tioned with an attenuation frequency characteristic to attenuate the amplitudes of said even harmonics such that the attenuated harmonics simulate substantially a modulated carrier wave comprising a carrier wave having a frequency corresponding to the frequency of a certain even harmonic and side-bands separated therefrom by bands equivalent to the frequency of the second harmonic and multiples thereof.

5. A signaling wave generator comprising in combination a source of alternating-current waves, means including a saturable magnetic-core coil applied across said fundamental source to produce a range of even harmonics, an output circuit including a capacitor so that said even harmonics are produced with uniformly large amplitudes extending over the entire range, and a frequency-selective means interposed in said output circuit and proportioned with an attenuation frequency characteristic to attenuate the amplitudes of said even harmonics such that a certain even harmonic possesses substantially the original amplitude and adjacent even harmonics have progressively decreasing amplitudes as the harmonic order decreases and increases relative to the harmonic order of said certain harmonic, the attenuated harmonics simulating substantially a modulated carrier wave comprising a carrier wave having a frequency corresponding to the frequency of said certain even harmonic and side-bands having frequencies corresponding to the frequencies of said adjacent even harmonics.

6. A system for producing harmonics comprising means for deriving from fundamental alternating current waves certain harmonics having substantially uniform amplitudes, a load circuit, and means for impressing said certain harmonics on said load circuit comprising a frequency selective network whose attenuation frequency characteristic is such that one harmonic is transmitted to said load circuit with substantially no transmission loss and adjacent harmonics are transmitted to said load circuit with progressively decreasing amounts of transmission loss as their harmonic order decreases and increases with respect to the harmonic order of said one harmonic, the harmonics in said load circuit simulating substantially a modulated carrier wave in which said one harmonic is equivalent to the carrier wave and said adjacent harmonics are equivalent to both the upper and lower side-bands.

7. A harmonic frequency producing system comprising a source of fundamental waves, means applied to said source to produce a predetermined range of both odd and even harmonics of said fundamental waves, an output circuit including an effective capacity applied to said harmonic producing means so that said odd and even harmonics are produced with uniformly large amplitudes over the predetermined range, and means comprising a frequency selective network interposed in said output circuit and proportioned with an attenuation frequency characteristic to attenuate the amplitudes of both said odd and even harmonics such that one harmonic is transmitted to said output circuit with substantially no transmission loss, next adjacent harmonics are transmitted to said load circuit with substantially six decibels transmission loss, and other adjacent harmonics are transmitted to said load circuit with progressively decreasing amounts of transmission loss as their harmonic order de-

creases and increases with respect to said next adjacent harmonics.

8. The harmonic frequency producing system according to claim 7 in which said frequency selective network comprises a parallel tuned circuit in shunt of said output circuit and a series tuned circuit in series in one side of said output circuit.

9. The harmonic frequency producing system according to claim 7 in which said harmonic producing means comprises a saturable magnetic core, input and output windings wound on said core, and a unidirectional element in shunt of said input winding.

10. The harmonic frequency producing system according to claim 7 in which said harmonic producing means comprises a saturable magnetic core, input and output windings wound thereon such that said input winding is applied to said fundamental source and said output winding is applied to said output circuit, a unidirectional element in shunt of said input winding, and said frequency selective network comprises a first capacity in shunt of said output circuit, a pair of inductances in series in one side of said circuit, a pair of other capacities in series between said pair of inductances, another capacity between a junction point of said pair of other capacities and the other side of said output circuit, and an inductance in shunt of said output circuit, said frequency selective network being an effective capacity outside of its pass-band.

11. A wave generator comprising means for deriving from an alternating current wave of fundamental frequency a range of odd harmonics having substantially uniform amplitudes, a load circuit, and means for impressing said harmonics

on said load circuit, comprising a frequency selective network having an attenuation-frequency characteristic such that one odd harmonic is transmitted to said load circuit with substantially no transmission loss and adjacent odd harmonics are transmitted to said load circuit with progressively decreasing amounts of transmission loss as their harmonic order decreases and increases relative to the harmonic order of said one odd harmonic, said odd harmonics in said load circuit simulating substantially a modulated carrier wave comprising a carrier wave having a frequency equivalent to the frequency of said one odd harmonic and side bands whose frequencies are equivalent to odd multiples of said fundamental frequency.

12. A wave generator comprising means for deriving from an alternating current wave of fundamental frequency a range of harmonics having substantially uniform amplitudes, a load circuit, and means for impressing said harmonics on said load circuit, comprising a frequency-selective network having an attenuation-frequency characteristic such that one harmonic is transmitted to said load circuit with substantially no transmission loss and adjacent harmonics are transmitted to said load circuit with progressively decreasing amounts of transmission loss as their harmonic order decreases and increases relative to the harmonic order of said one harmonic, said harmonics in said load circuit simulating substantially a signal modulated carrier wave comprising a carrier wave having a frequency equivalent to the frequency of said one harmonic and modulated with a signal wave having a frequency which is a multiple of said fundamental frequency.

LEISHMAN R. WRATHALL.