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H. A. AFFEL

HARMONIC GENERATOR

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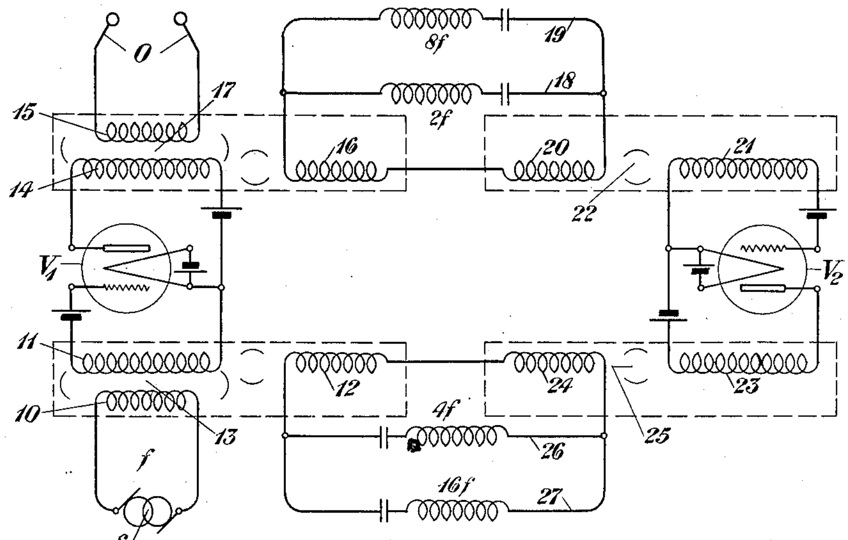

Fig. 1

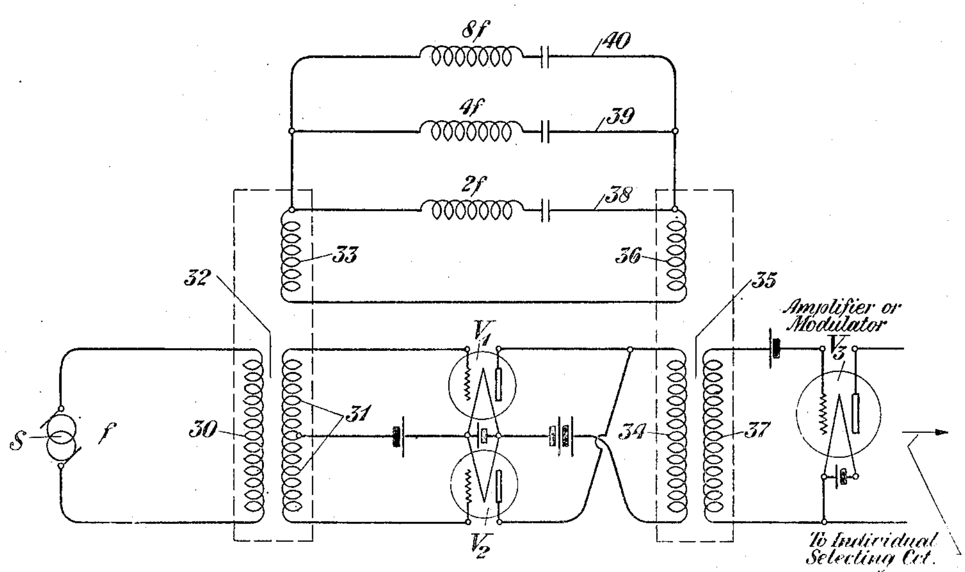

Fig. 2

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Fig. 3

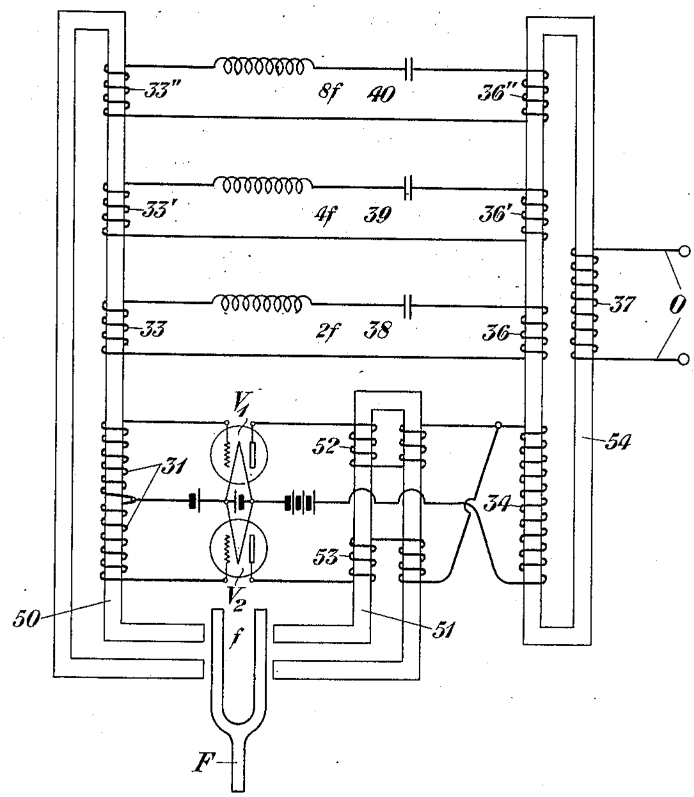
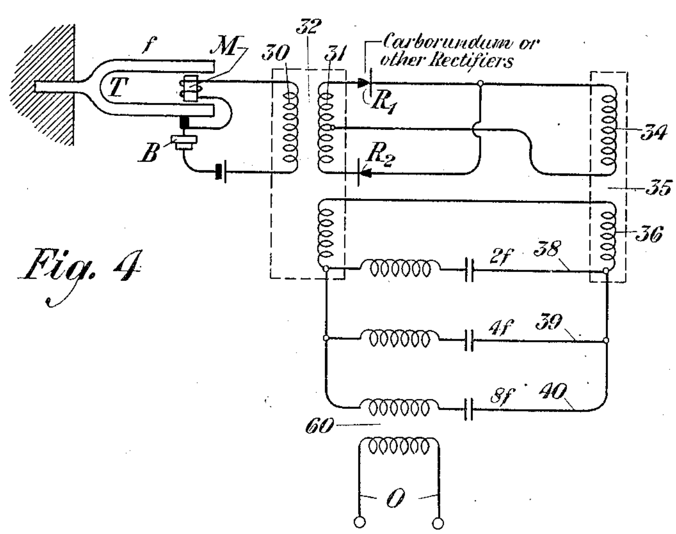


Fig. 4



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UNITED STATES PATENT OFFICE.

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HARMONIC GENERATOR.

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This invention relates to high frequency generation and more particularly to the generation of high frequencies by means of harmonic producers.

In carrier signaling systems it has, to some extent, been the practice to generate the carrier frequencies for the different signaling channels by a process of harmonic generation. Heretofore, this method has been used, however, only with relatively low harmonics. It is possible, however, to obtain high harmonics by generating the high frequencies in a number of steps, that is, by generating first a relatively low harmonic in one distorting device, such as a vacuum tube, for example, and successively multiplying the frequency thus produced by passing it through other tandem distorting circuits.

In accordance with the present invention it is proposed to attain this successive or cascade generation of harmonics by means of a feed-back circuit so that only one distorting device or tube may be needed to effect the successive frequency transformations. It should be noted that a feed-back circuit of this type differs from the ordinary feed-back circuit in that a different frequency from the frequency originally applied to the tube is led from the output to the input circuit so that no singing effect will result.

The invention may now be more fully understood from the following detailed description when read in connection with the accompanying drawing, Figure 1 of which is a simplified circuit diagram illustrating one embodiment of the invention and Figures 2, 3 and 4 of which are circuit diagrams illustrating alternative embodiments of the invention.

Referring to Fig. 1, S denotes some suitable source of alternating current having a frequency f and V_1 designates a vacuum tube device of well known type whose constants are so adjusted that it distorts the wave form of any electromotive force impressed thereon. The source S is coupled to the input circuit of the distorting tube V_1 through windings 10 and 11 of a transformer 13. The output circuit of the distorting tube is coupled to an outgoing circuit O through windings 14 and 15 of a transformer 17. A third winding 16 of the transformer 17 is inductively related to the winding 14 and is connected in circuit with a plurality of selecting circuits 18 and 19, each tuned to a desired harmonic frequency of the fundamental frequency generated by the source S.

The selecting circuits 18 and 19 are coupled to the input circuit of a vacuum tube distorting device V_2 through windings 20 and 21 of a transformer 22. The vacuum tube device V_2 is similar to the device V_1 already described. The output circuit of the distorting tube V_2 is coupled through windings 23 and 24 of a transformer 25 to another group of selecting circuits 26 and 27, each tuned to suitable harmonics of the fundamental frequency f. These selecting circuits are coupled to the input circuit of the first distorting device V_1 through windings 11 and 12 of the transformer 13. It will thus be seen that a complete circular path for the transmission of energy at successive frequencies is provided.

The operation is as follows: The frequency f, impressed upon the input circuit of the distorting device V_1, results in the production in the output circuit of said device of various harmonic frequencies of the fundamental frequency, among which the second harmonic 2^f will be prominent. The second harmonic 2^f will be transmitted directly to the outgoing circuit O and will also be transmitted through the winding 16 to the tuned circuit 18. The latter, by reason of its coupling to the input circuit of the distorting device V_2 will transmit the frequency 2^f to said distorting device so that the second harmonic of this frequency, or 4^f, will appear in the output circuit thereof. The frequency 4^f will in turn be selected by the tuned circuit 26 and transmitted through the transformer 13 to the input circuit of the original distorting device V_1. The latter will in turn produce in its output circuit, the second harmonic frequency 8^f of the frequency 4^f. The harmonic frequency 8^f will be transmitted directly to the outgoing circuit O and will also be transmitted through the selective circuit 19 to the distorting device V_2, which produces a second harmonic (16^f) of the frequency 8^f. The frequency 16^f is selected by the tuned circuit 27 and impressed upon the input circuit of the original distorting device V_1 so that the second harmonic of the frequency 16^f, or a frequency 32^f, will be impressed upon the outgoing circuit O.

In addition to the frequencies already mentioned as being transmitted directly to the outgoing circuit O, it is apparent that all of the fundamental frequencies impressed upon the input circuit of the vacuum tube V_1 will also appear in the output circuit so that the frequencies f, 4^f and 16^f will be directly transmitted to the outgoing circuit O in addition to the harmonics noted. Also it will be apparent that since the distorting tubes are, in effect, modulating devices, all of the frequencies impressed upon the distorting device V_1 will modulate each other to produce sum and difference frequencies as well as harmonics, and these sum and difference frequencies may be transmitted directly to the outgoing circuit O. As a consequence, practically any harmonic of the fundamental frequency f may be obtained in the outgoing circuit O and, by providing suitable selective devices in the outgoing circuit O, any desired harmonic may be segregated for any purpose desired.

It will be observed that the system above described provides for the recurrent transmission of energy through a circular path, the energy being translated in frequency at each successive stage of its transmission through the path.

A modified arrangement for attaining the results above outlined is illustrated in Fig. 2. In this case, a balanced vacuum tube circuit involving the tubes V_1 and V_2 is employed, the circuit being of a well known type so arranged that the amplification component may be suppressed and the double frequencies transmitted. The alternating current source S is coupled to the input circuit of the balanced vacuum tube arrangement through windings 30 and 31 of a transformer 32. The output circuit of the balanced vacuum tube arrangement is provided with a winding 34 of a transformer 35 in the common branch of said output circuit and the winding 34 is inductively related to a winding 36 associated with a series of tuned selecting circuits 38, 39 and 40, each tuned to particular harmonics of the fundamental frequency f. The tuned circuits 38, 39 and 40 are coupled to the input circuit of the balanced vacuum tube arrangement through the winding 33 inductively related to the winding 31 of the transformer 32. If desired, an additional tube V_3 may be associated with the output circuit of the distorting tube arrangement V_1, V_2 through a winding 37 inductively related to the winding 34. The tube V_3 may be utilized either to amplify frequencies transmitted thereto or to modulate together a plurality of frequencies transmitted thereto, thereby producing sum and difference frequencies of such individual frequencies.

The operation is as follows: The frequency f, upon being impressed upon the distorting tubes V_1 and V_2 produces in the common output branch including the winding 34, even harmonics of the frequency f. The odd harmonics including the fundamental f will be suppressed. The second harmonic 2^f will be transmitted through the windings 34 and 36 to the tuned circuit 38 and in turn will be transmitted from the tuned circuit 38 through the windings 33 and 31 to the input circuit of the balanced distorting arrangement. This will result in the production of a frequency 4^f in the output circuit, which will be selected by the tuned circuit 39 and impressed upon the input circuit of the distorting tubes V_1 and V_2. The second harmonic (8^f) of this frequency will appear in the output and will be selected by circuit 40 to be applied to tubes V_1 and V_2, so that finally a frequency 16^f will be produced and transmitted through the windings 34 and 37 to the input circuit of the vacuum tube V_3.

The other frequencies generated in the winding 34 such, for example, as the frequencies 2^f, 4^f and 8^f, will also be impressed upon the input circuit of the tube V_3. If the tube V_3 is adjusted to operate as an amplifier these frequencies will be amplified directly and may be selected individually into suitable circuits for any purpose desired. If, however, the tube V_3 be adjusted to operate as a modulator it will produce frequencies corresponding to the sums and differences between the several frequencies impressed upon its input circuit so that in the output circuit there will appear frequencies corresponding to these sums and differences, as well as to the several harmonics already referred to.

It will be noted that by reason of the balanced arrangement of the vacuum tubes V_1 and V_2, no singing is possible as the fundamental frequency f is balanced out as regards the winding 34, which is included in the common branch of the output circuit.

It will also be noted that in the above circuit continuous oscillation or singing cannot take place at any frequency since any frequency transmitted to the input circuit will be balanced out in the output circuit and not be transmitted back to the input circuit.

A circuit arrangement such as that above described is peculiarly advantageous as it enables the production of any high frequency desired from a very low fundamental frequency. Thus, a tuning fork, for example, may be used to control the generation of a low fundamental frequency which will be very accurately determined and the corresponding harmonics of the fundamental frequency will be likewise accurately fixed with respect to frequency. A circuit arrangement illustrating this principle is shown in Fig. 3, in which the tuning fork F is magnetically associated with U-shaped cores 50 and 51, so that the tines of the fork form a path for the flux passing from one leg of the U to the other. The input winding 31 of a balanced distorting tube arrangement V_1, V_2, such as that illustrated in Fig. 2, is wound upon the core 50, while windings 52 and 53, included in the individual branches of the plate circuits of the balanced arrangement, are wound upon the core 51. A winding 34, included in the common branch of the output circuit, is wound upon a core 54, having inductively associated therewith a winding 37 included in an outgoing circuit O. The core 54 also includes windings 36, 36′ and 36″ associated with tuned circuits 38, 39 and 40. Each of the tuned circuits just referred to includes an individual winding upon the core 50, as indicated at 33, 33′ and 33″.

The operation is as follows: Assuming that the tuning fork F is set into vibration so that the tines of the fork vibrate alternately toward and away from each other at a frequency f, it is apparent that the vibration of the left-hand tine produces changes in the flux of the core 50, these changes in turn producing potential fluctuations of the same frequency upon the grids of the vacuum tubes V_1 and V_2. Since the vacuum tubes V_1 and V_2 are distorting devices, even and odd harmonics will be produced, the even harmonics flowing through the winding 34 and the odd harmonics being balanced therefrom, while the odd harmonics flow through the windings 52 and 53, the even harmonics being prevented from flowing through these windings by the balanced arrangement of the circuit. The fundamental frequency f will consequently appear in the windings 52 and 53, thereby producing changes in the flux in the core 51 and causing the tines of the tuning fork F to vibrate in correspondence therewith. As a consequence, the tuning fork F, once set in vibration, continues to vibrate owing to the mechanical feed-back connection between the output and the input circuits through the cores 51 and 50 and the tuning fork F.

The second harmonic 2^f, flowing through the winding 34, will be transmitted through the winding 36 to the tuned circuit 38 and impressed through windings 33 and 31 upon the input circuit of the balanced distorting device, thereby producing a frequency 4^f in winding 34 of the output circuit. This frequency is in turn selected by the circuit 39 and impressed upon the input circuit to produce a frequency 8^f, which in its turn is also fed back to the input circuit, finally producing a frequency 16^f in the winding 34. As a consequence, the several even harmonic frequencies referred to will be transmitted through the coupling of windings 34 and 37 to the outgoing circuit O and may be utilized in any desired manner.

Instead of using vacuum tube devices for distorting purposes, as illustrated in Fig. 2, any type of rectifying device may be used, as indicated at R_1 and R_2 of Fig. 4. It will be noted that in this figure the winding 34 is included in a common branch of the balanced circuit arrangement so that only even harmonics will flow through this winding and the fundamental or any other frequency impressed upon the winding 31 cannot be fed back to said winding through the transformer windings 34 and 36. The fundamental frequency f is generated by a mechanically operated tuning fork T, the tuning fork being actuated by a magnet M included in circuit with the winding 30 of transformer 32, a suitable source of current and an interrupting or resistance changing device B mechanically actuated by the tine of the tuning fork. The tuning fork is thus arranged to automatically control the energization of the magnet M so that its action will be continuous to supply a periodically variable current to the winding 30.

The operation will, of course, be obvious. The rectifying devices R_1 and R_2 distort the frequency impressed upon the winding 31 to produce harmonics and the second harmonic is selected by the tuned circuit 38 and impressed upon the input winding 31. The second harmonic of this frequency in turn appears in the output circuit and is selected by the circuit 39 and impressed upon the input winding 31. Finally, the second harmonic of this frequency (8^f) is produced in the output circuit and selected by the circuit 40. The frequency 8^f is then transmitted from the circuit 40 through the transformer 60 to the outgoing circuit O.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. A harmonic generator comprising a source of fundamental frequency, a static translating device upon which said fundamental frequency may be impressed, said static translating device having an input circuit and an output circuit and being adapted to produce harmonics of the fundamental frequency, a reentrant connection from the output circuit of said translating device to its input circuit, said reentrant connection comprising a plurality of paths each adapted to feed back into the input circuit of

said translating device a different harmonic frequency produced in the output circuit thereof, thereby producing frequencies which are harmonics of the frequencies fed back, and means to prevent alternate harmonics from being fed back.

2. A harmonic generator comprising a source of fundamental frequency, a vacuum tube translating device upon which said fundamental frequency may be impressed, said vacuum tube translating device having an input circuit and an output circuit and being adapted to produce harmonics of the fundamental frequency, and a reentrant connection from the output circuit of said vacuum tube translating device to its input circuit, said reentrant connection comprising a plurality of paths each adapted to feed back into the input circuit of said vacuum tube translating device a different harmonic frequency produced in the output circuit thereof, thereby producing frequencies which are harmonics of the frequencies fed back, and means to prevent alternate harmonics from being fed back.

3. A harmonic generator comprising a source of fundamental frequency, a distorting device upon which said fundamental frequency may be impressed, said distorting device having an input circuit and an output circuit and being adapted to produce harmonics of said fundamental frequency, a reentrant circuit connecting the output circuit of the distorting device with its input circuit, said reentrant circuit having a plurality of paths each arranged to feed back energy corresponding to different even harmonics of the fundamental frequency, and means to prevent the feeding back of the energy of the fundamental frequency or odd harmonics thereof.

In testimony whereof, I have signed my name to this specification this 14th day of May 1923.

HERMAN A. AFFEL.