

Nov. 12, 1957

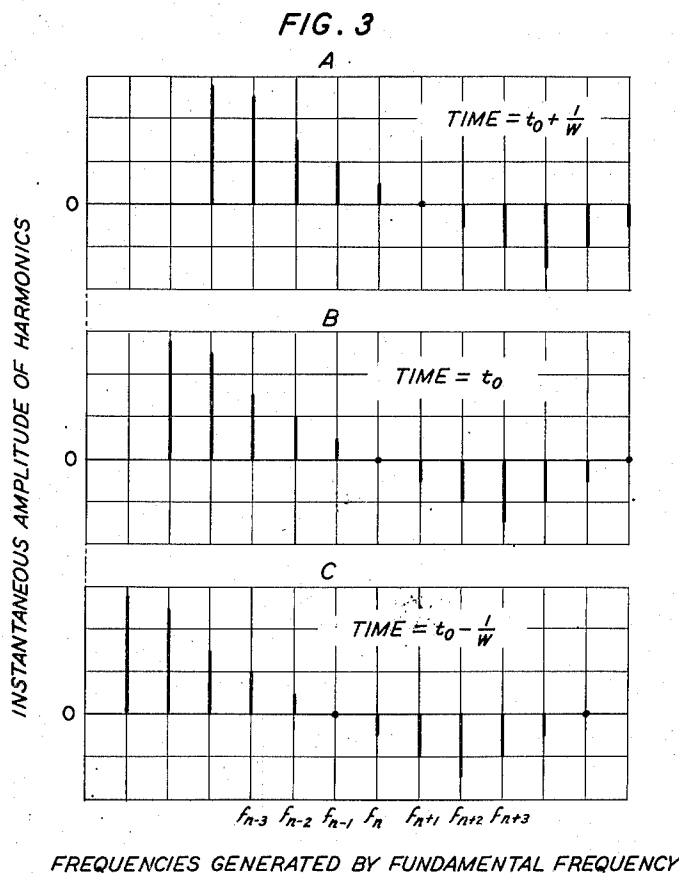
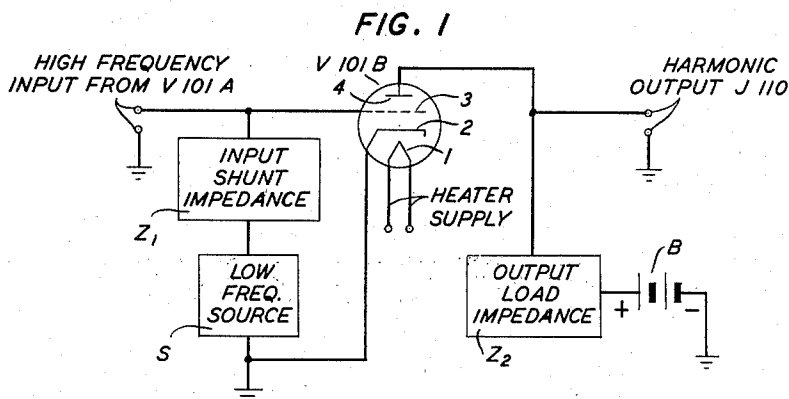
E. HEBER

2,813,200

HARMONIC GENERATOR APPARATUS

Filed April 29, 1955

2 Sheets-Sheet 1



INVENTOR
E. HEBER
BY *w. g. o'neill*
ATTORNEY

1

2,813,200

HARMONIC GENERATOR APPARATUS

Emery Heber, West Orange, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application April 29, 1955, Serial No. 504,780

5 Claims. (Cl. 250—36)

This invention relates to harmonic generator apparatus, and particularly to harmonic producers which may be utilized as signal generators or calibrators for radio sets, as modulators for radio communication purposes, and for other purposes.

One of the objects of this invention is to provide harmonic generators of improved performance.

Another object of this invention is to provide a more uniform frequency spectrum in a harmonic generator.

Another object of this invention is to increase the amplitude of low level harmonics generated by a harmonic generator.

Another object of this invention is to modulate the frequency spectrum of a harmonic generator.

Harmonic generators may generate harmonics by distortion of the input wave shape in a non-linear circuit element which may comprise a triode or other vacuum type amplifier tube biased for Class C operation with grid bias considerably beyond cut-off. A further and continuous distortion of the wave shape may be obtained by injecting into the tube, as into grid-cathode circuit thereof, a continuously variable bias voltage which may be provided by means of a suitable source of continually changing bias voltage, in accordance with a feature of this invention.

Such continual variation of the bias voltage applied to the harmonic generator may be accomplished by means of a suitable low frequency source, and may be utilized to raise the amplitudes of low level harmonics to usable values for harmonics up to the 100th harmonic for example, or higher, for use as a calibrator and other purposes; also, it may be utilized to modulate the harmonic frequency spectrum produced by the continually changing grid bias of the harmonic generator.

The low frequency source of bias voltage may be an alternating voltage source of 60 cycles per second, or of audio frequencies, or of other continually changing voltage such as continually varying voltage from a rectifier. In the case of audio frequencies, the audio modulating voltage introduced varies the bias and thus the frequency spectrum of the harmonics of the harmonic generator.

Some of the harmonics of harmonic generators of conventional design known in the prior art do not have sufficient amplitudes to meet a desired level, and moreover some of such harmonics may be absent or missing from the frequency spectrum comprising both the odd and even order integral multiples of the fundamental frequency. The present invention may be utilized to provide sufficiently high level amplitudes for all harmonics, where the prior art designs failed in this respect.

For a clearer understanding of the nature of this invention and the additional advantages, features and objects thereof, reference is made to the following description taken in connection with the accompanying drawings, in which like reference characters represent like or similar parts and in which:

Fig. 1 is a circuit diagram illustrating in block diagram

2

form harmonic generator apparatus in accordance with this invention;

Fig. 2 is a schematic circuit diagram illustrating an embodiment of the harmonic generator apparatus shown in Fig. 1; and

Figs. 3A, 3B and 3C are a set of graphs illustrating modulation of the frequency spectrum that may be produced by a continually changing grid bias of the harmonic generator shown in Figs. 1 and 2.

Referring to the drawing, Fig. 1 is a circuit diagram illustrating in block diagram form harmonic generator apparatus. As shown in Fig. 1, the circuit may generally comprise a source of radio frequency input waves from V101A, and a harmonic generator tube V101B with associated circuits for producing from the fundamental frequency input waves received from the oscillator source V101A, a series of integral multiple harmonics thereof at the harmonic output terminals J110.

The harmonic generator tube V101B, as shown in Fig. 1, may comprise a vacuum type triode amplifier tube having a cathode heater 1 which may be energized by a suitable heater supply power source, a grounded cathode electrode 2, an input control grid electrode 3 which may be connected with the high frequency input source V101A to receive excitation energy therefrom of sine wave form, and an output circuit anode or plate electrode 4 which may be energized by a suitable source of direct current power supply voltage B+ through a suitable output load impedance Z2.

As shown in Fig. 1, the grid-cathode circuit 2, 3 of the harmonic generator V101B may comprise a suitable input shunt impedance Z1 for Class C amplifier operation, and a source of low frequency voltage S which may be injected at any point in the grid-cathode circuit 2, 3 of the harmonic generator tube V101B and utilized to continually change the grid bias voltage, for such purposes as to alter the relative amplitudes of the harmonics and modulate the harmonic frequency spectrum, in accordance with a feature of this invention.

The source S of low frequency bias voltage for continually changing the grid bias of the harmonic generator tube V101B may comprise, for example, an alternating current source of 60 cycles per second which may be obtained from the cathode heater power supply source as shown in Fig. 2.

The input shunt impedance Z1 and the output load impedance Z2 may comprise any suitable impedances, such as those shown in Fig. 2.

Fig. 2 is a schematic diagram illustrating an example of a circuit embodiment of harmonic generator apparatus shown in block diagram form in Fig. 1. As shown in Fig. 2, the assembly may comprise generally a crystal oscillator at V101A followed by a harmonic generator at V101B producing a spectrum, band or range of harmonic frequencies at output coaxial jack J110.

As shown in Fig. 2, the crystal oscillator V101A may comprise one-half V101A of a conventional duo-triode vacuum tube V101A and V101B, with the tube section V101A having an anode or plate electrode 6, a control grid electrode 7, a grounded cathode electrode 8 and a cathode heater 9. A shielded frequency-controlling piezoelectric crystal unit Y101 may be provided in the input grid-cathode circuit 7, 8; and a shunt condenser C108, and grid resistors R101 and R102 may be provided as shown. The plate output circuit of the oscillator tube V101A, as shown in Fig. 2, may comprise a tuned tank circuit which may consist of a variable inductance winding L107 and condenser C110, with a condenser C111 in the circuit between the plate electrode 6 and cathode electrode 8, the tuned circuit being tuned to the frequency of the crystal Y101 to provide stable output sine wave

oscillations which may be transmitted through a coupling condenser C112 to the harmonic generator V101B.

As shown in Fig. 2, plate supply voltage for the plate electrode 6 of the oscillator tube V101A may be obtained from a suitable direct current plate supply source +B as provided through coil L139, resistor R103 and tank circuit inductance winding L107. Heater supply current for the cathode heater 9 of the oscillator tube V101A may be obtained from a grounded alternating current heater supply source through coils L110, L138, and cathode heaters 9 of tube section V101A and 1 of tube section V101B, as shown in Fig. 2. Suitable grounded shunt condensers C118, C291 and C289 may be provided in the cathode heater supply circuit as shown in Fig. 2. Also, suitable grounded shunt condensers C293, C283 and C290 may be provided in the +B plate supply circuit as shown in Fig. 2.

As shown in Fig. 2, the harmonic generator per se may comprise the other half V101B of a conventional duotriode vacuum tube V101A and V101B, with tube section V101B having a grounded cathode heater 1 which may be energized by the common alternating current heater supply source through coils L110 and L138 and cathode heater 9 of tube V101A connected in series with the cathode heater 1 of tube V101B. The tube V101B also has a grounded cathode electrode 2, and an input control grid electrode 3 which is energized by radio frequency sine waves received from the output tank circuit L107, C110 of the crystal oscillator V101A through coupling condenser C112, and which is biased for Class C amplifier operation by grid-leak resistor R104 corresponding to the input shunt impedance Z1 of Fig. 1. As shown in Fig. 2, the grid electrode 3 of the harmonic generator tube V101B is also supplied with continuously variable grid bias voltage from the low frequency heater supply source of 60 cycles per second, corresponding to the low frequency source S of Fig. 1, which is injected into the grid-cathode circuit 2, 3 of tube V101B in accordance with a feature of this invention. The plate electrode 4 of tube V101B may be supplied with direct current plate supply voltage from the +B source through coil L139 and resistors R106 and R105; and the output from plate 4 also supplies a band of harmonic frequencies, which are integral multiples of the fundamental high frequency input at V101A, to the output jack terminals J110 through condensers C288 and C292 shunted by grounded resistors R321 and R323. Resistor R105 may be considered as corresponding to the output load impedance Z2 of Fig. 1. Condenser C284 serves as a bypass capacitor to connect the load impedance to the cathode of the harmonic generator tube V101B.

As shown in Fig. 2, the fundamental frequency output of the oscillator V101A is capacity coupled through capacitor C112 to the grid electrode 3 of the harmonic generator amplifier stage V101B. The peaks of the positive half of the fundamental high frequency input from V101A cause the flow of grid current in tube V101B which current produces a bias voltage across the grid leak resistor R104 and this causes the tube V101B to operate Class C and produce an output rich in the harmonics of the 11 megacycles per second input fundamental frequency. The grid resistor R104, as shown in Fig. 2, is connected to the alternating current heater voltage supply line and the 60 cycles per second variations therefrom produce corresponding changes in the output wave form. Thus, the amplitude of the grid drive on the harmonic generator V101B is continually varied at 60 cycles per second resulting in an equalizing effect on the harmonic output levels, in accordance with a feature of this invention.

As shown in Fig. 2, the plate load consists of the resistor R105, and the harmonic output of the amplifier V101B is coupled to the output coaxial jack terminals J110 through the high-pass filter network comprising the series capacitors C288 and C292 and the shunt resistors R321 and R323. The plate voltage from the power supply source +B is filtered by the capacitors C283, C293 and C290 and

the inductor L139 and by other components as resistor R106 and capacitor C284. The shunt capacitors C118, C289 and C291 and the series inductors L110 and L138 form a radio frequency filtering network to prevent the high frequency energy from flowing in the 60 cycles per second heater supply circuits and in other portions of the radio equipment.

As an illustrative example in a particular case for the harmonic generator apparatus shown in Fig. 2, considered as having a radio frequency input from the oscillator V101A of 11 megacycles per second (11 mc.) fundamental frequency and considered as producing at output coaxial J110 a band of integral multiple harmonic frequencies thereof between 55 and 605 megacycles per second for example, the component resistors, capacitors, inductors and other components of the circuit shown in Fig. 2 may have values as marked and indicated on the drawing in Fig. 2, wherein the condenser values are expressed in micro-microfarads, the resistor values in ohms, and the inductance values in microhenries. The dual-triode tube V101A—V101B may be a type 5670 vacuum tube, the +B power supply may be 150 volts, and the heater supply may be 6.3 volts, 60 cycles per second.

It will be noted that the grid circuit 3 of the harmonic generator tube V101B of Fig. 2 for radio frequencies is completed through the cathode 2 by means of the grid-leak resistor R104, the coil L138, the capacitor C291 and the common ground connection between the capacitor C291 and the cathode 2. The low frequency source of 60 cycles per second voltage for continually changing the grid bias of the harmonic generator tube V101B may be introduced at any point of this grid-cathode circuit.

It will be noted that the 60 cycle voltage is applied, in Fig. 2, to the grid electrode 3 of the harmonic generator tube V101B by injecting it into the grid-cathode circuit 2, 3 thereof by returning the grid resistor R104 to the heater supply, in accordance with a feature of this invention. In the absence of this feature and with an ideal pulse input the average amplitude of the higher frequency harmonics of a harmonic generator theoretically would decrease progressively. If each successive harmonic be examined in a practical harmonic generator, occasional smaller or larger amplitudes would be observed. These departures are primarily a result of the nature of the high frequency waveform applied to the grid electrode 3 of the harmonic generator tube V101B and the operating characteristics of the generator tube. However, a small change in the input waveform or a change in the operating characteristics of the tube will cause these observed variations of output to occur at a new set of harmonic frequencies and if a continuous spectrum is desired, no improvement would be effected by such change. The application of the low-frequency 60 cycles per second voltage to the grid electrode 3 of the harmonic generator V101B, in accordance with a feature of this invention, causes continuous changing of the input waveshape or operating conditions of the tube which in turn causes the amplitudes of the various harmonic components to wobble and shift up and down, thereby increasing the amplitudes of the low valued or missing components to values which may be usable.

The method is based on the fact that the amplitude of the nth harmonic produced by the fundamental wave shape depends, among other factors, upon the amplitude and rise time of the generated pulses, as may be shown by the application of Fourier's analyses to the pulse wave form. Accordingly, by continually changing the pulse shape, the harmonics whose amplitudes are low or zero valued may be continually shifted in the frequency spectrum, thereby in effect increasing the amplitude of these harmonics.

This rate of wobble or shift referred to may be achieved by the injection of the continuously variable bias voltage, such as a voltage of 60 cycles per second for example, into the grid circuit 3 of the harmonic generator

tube V101b at any point in the grid-cathode circuit 2, 3 thereof. As shown in Fig. 2, this may be accomplished by the return of the grid leak resistor R104 to the low voltage heater supply source. It will be noted that this continuously variable bias voltage on the grid 3 of the harmonic generator tube V101b results in a continuous change of the height and shape distortion of the pulses appearing at the grid electrode 3, and the continuously changing pulse shape in turn produces a continuous shift or wobble in the location of the harmonics in the frequency spectrum, and this continual shifting results in an increased amplitude of the lowest level harmonics and a reduced amplitude of the higher level adjacent harmonics.

Figs. 3A, 3B and 3C are a set of three graphs illustrating an example of the modulation of the frequency spectrum produced by the continually changing grid bias of the harmonic generator shown in Figs. 1 and 2.

As shown in Figs. 3A, 3B and 3C, the abscissae represent the harmonic frequencies, f_n and the adjacent harmonics f_{n+1} , f_{n-1} etc. which are generated by the fundamental frequency f ; and the ordinates represent the instantaneous amplitudes of such harmonics, where f_n is the n th order harmonic having a very low or a zero amplitude as shown in the respective graphs in Figs. 3A, 3B and 3C at f_n . Fig. 3B represents the frequency spectrum at a time t_0 when the instantaneous amplitude of the harmonic f_n is zero. Figs. 3A and 3C represent the frequency spectrum at a time $t_0 + 1/w$ and $t_0 - 1/w$ respectively when the instantaneous amplitudes of the harmonic f_n are very low. In these equations, w = the angular velocity of the low frequency modulating source introduced in the grid circuit 3 of the harmonic generator V101B of Figs. 1 and 2; and t_0 is at a time when $w = 0$.

As shown in Figs. 3A, 3B and 3C, the maximum amplitude of the n th order harmonic f_n is raised or lowered together with the amplitudes of the adjacent harmonics f_{n+1} , f_{n-1} etc., in accordance with the grid bias change produced by the low frequency source S of the harmonic generator V101B of Figs. 1 and 2. The instantaneous amplitude change of the harmonic peaks in the picket-fence type frequency spectrum shown in Figs. 3A, 3B and 3C, which may be caused by the continuous change of the grid bias of the harmonic generator V101B of Figs. 1 and 2, is a type of modulation which may be used for communication and other purposes. It will be noted that this type of modulation is a modulation of the frequency spectrum, rather than amplitude modulation, frequency modulation, phase modulation, or pulse amplitude modulation.

While the invention has been particularly described and illustrated herein as applied to a triode having the low frequency bias voltage injected into the control grid electrode thereof, it may be also applied to a tetrode or a pentode by introducing the low frequency voltage into the control grid or into the screen grid electrode thereof, and adjusting the amplitude of the low frequency voltage accordingly.

Although this invention has been described and illustrated in relation to specific arrangements, it is to be understood that it is capable of application in other organizations and is therefore not to be limited to the particular embodiments disclosed.

What is claimed is:

1. Harmonic generator apparatus comprising a source of radio frequency waves, and means for generating higher frequency harmonics from said source waves comprising

an electronic vacuum tube having grid, anode and cathode electrodes and a cathode heater for said cathode electrode, an output load impedance in circuit between said anode and cathode electrodes, an input shunt impedance in circuit between said grid and cathode electrodes, and means including a common source of low frequency voltage for supplying current to said cathode heater and for simultaneously supplying said grid electrode with continually variable grid bias voltage sufficient to alter the relative amplitudes of said harmonics in accordance with said continually variable grid bias voltage.

2. Harmonic generator apparatus comprising a source of oscillating signals, nonlinear circuit means producing sufficient wave shape distortion of said signals for generating higher frequency harmonics thereof, means including a source of varying voltage having a frequency less than the frequency of said signals, means for applying said voltage to said nonlinear circuit, means for varying the degree of said wave shape distortion, means having a substantially constant impedance at the frequencies of said harmonics connected to the output of said nonlinear circuit means, and means making said harmonics available as the output of said apparatus.

3. Harmonic generator apparatus comprising a source of oscillating signals, means including a thermionic vacuum tube producing sufficient wave shape distortion of said signals for generating higher frequency harmonics thereof, means including a source of varying bias voltage having a frequency less than the frequency of said signals, means for injecting said voltage into the grid circuit of said tube for varying the degree of said wave shape distortion, means having a substantially constant impedance at the frequencies of said harmonics connected to the output of said tube, and means making said harmonics available as the output of said apparatus.

4. Harmonic generator apparatus comprising a source of oscillating signals, means including a thermionic vacuum tube having cathode, grid, and anode electrodes for producing sufficient wave shape distortion of said signals for generating higher frequency harmonics thereof, means including a source of varying voltage having a frequency less than the frequency of said signals, means for applying said voltage to said grid electrode of said tube for continuously changing the degree of said wave shape distortion, means having a substantially constant impedance at the frequencies of said harmonics connected to said anode electrode, and means making said harmonics available as the output of said apparatus.

5. Harmonic generator apparatus comprising a source of oscillating signals, a thermionic vacuum tube having grid, cathode, and anode electrodes, means connecting said source to said grid electrode, means having a substantially constant impedance at the frequencies of said harmonics connected to said anode electrode, means for energizing said tube for generating harmonics of said signals, means including a source of varying voltage having a frequency less than the frequency of said signals, means for applying said voltage to said grid electrode for varying the amplitude of at least one of said harmonics, and means making said harmonics available as the output of said apparatus.

References Cited in the file of this patent

UNITED STATES PATENTS

1,559,869	Hartley	Nov. 6, 1925
2,298,099	Roberts	Oct. 6, 1942
2,484,763	Sturm	Oct. 11, 1949