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HIGH-FREQUENCY OSCILLATOR

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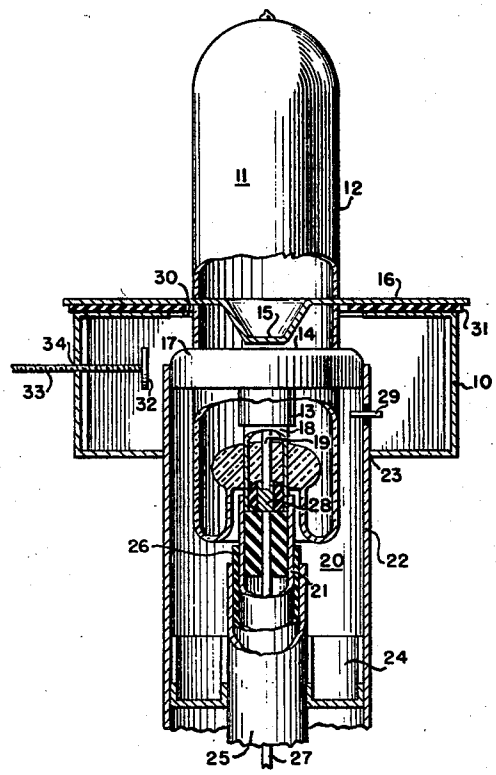


FIG. 1

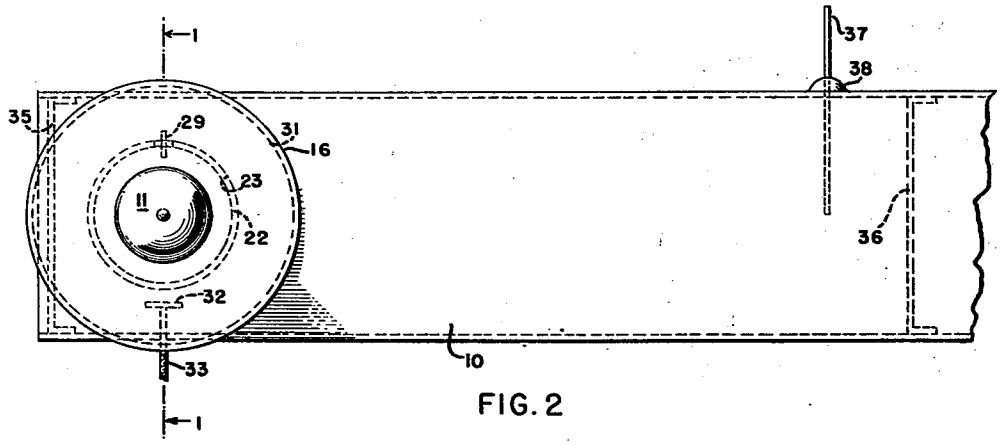


FIG. 2

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HIGH-FREQUENCY OSCILLATOR

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15 Claims. (Cl. 315—39)

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The present invention relates to high-frequency oscillators and, particularly, to oscillators of the type adapted to generate oscillations of a few centimeters wave length. In greater particularity, the invention relates to such oscillators of the triode-tube type.

Of the several types of high-frequency oscillators which heretofore have been proposed, the triode vacuum-tube type possesses numerous advantages not the least of which is its low operating-voltage requirements. One such well-known oscillator, termed the Barkhausen oscillator, operates the grid of the triode tube at a moderately high positive potential and the anode preferably at a slightly negative potential. The operation of this oscillator is dependent upon the fact that most of the electrons attracted by the grid pass between the meshes thereof toward the anode but have their velocities slowed down by the latter and are returned back to the grid. Most of the returning electrons again pass between the meshes of the grid, are slowed down by the cathode, and returned back toward the grid. The electrons thus oscillate about the grid at a frequency determined by the electrode voltages and the distances between the electrodes. This typ of oscillator has the disadvantage that the power output and efficiency of operation are quite critical with respect to circuit adjustments and the operating voltages applied to the tube electrodes. Optimum operation usually occurs when the temperature of the cathode is maintained sufficiently low that only a limited number of electrons are emitted so that the operating conditions within the tube are intermediate between the space-charge limited and temperature-limited space-current modes of operation. This has the serious disadvantage that the efficiency obtainable is relatively low, of the order of 1 to 3 per cent., thus substantially lowering the maximum power output of the oscillator. This type of oscillator has the additional disadvantage that the power output is further limited by the fact that the grid must absorb most of the lost power which, of course, constitutes the major portion of the power supplied to the oscillator and which can never be very large for the reason that the grid must necessarily be small and of a type of structure not capable of dissipating large amounts of energy.

A triode vacuum-tube type of high-frequency oscillator operates with substantially improved efficiency and considerably larger power output as compared with the Barkhausen oscillator when the oscillator circuit arrangement is of more conventional form and includes an input circuit coupled between the control electrode and cathode and an output circuit coupled between the anode and cathode of the triode vacuum tube. The input and output circuits of an oscillator of this type usually take the form of transmission lines which have resonant properties when their lengths are suitably adjusted. Severe difficulty is experienced in operating these oscillators at frequencies much higher than about three hundred megacycles, which corresponds to a wave length of one meter, so that, in general, they are not suitable for the generation of oscillations of a few centimeters wave length.

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It is an object of the present invention, therefore, to provide a new and improved high-frequency oscillator.

It is a further object of the invention to provide a new and improved high-frequency oscillator of the triode-tube type which avoids one or more of the limitations and disadvantages of the prior arrangements of this type.

It is an additional object of the invention to provide a new and improved high-frequency oscillator having a relatively simple and compact yet sturdy construction and one having relatively high frequency stability.

In accordance with the invention, a high-frequency oscillator comprises a wave guide having dimensions proportioned substantially to attenuate oscillations of a fundamental frequency and to translate oscillations of higher frequency harmonically related to the fundamental-frequency oscillations. The oscillator includes a vacuum tube having input and output electrodes positioned with at least one pair of the electrodes lying within the wave guide and continued electrically by the walls thereof, and means resonant at the fundamental frequency and having substantial regenerative coupling to the wave guide for providing a resonant circuit between another pair of the electrodes to cause the vacuum tube to generate in the wave guide oscillations having the aforesaid fundamental frequency but including a frequency component of the aforesaid higher frequency.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

Referring to the drawing, Fig. 1 is a cross-sectional view illustrating the construction of a high-frequency oscillator embodying the present inven-

tion; and Fig. 2 is a plan view of the Fig. 1 arrangement.

Referring now more particularly to Fig. 1 of the drawing, there is illustrated, in cross-sectional view, the constructional details of a high-frequency oscillator embodying the present invention in a preferred form. The oscillator includes a wave guide 10 having dimensions proportioned, in a manner now well known, substantially to attenuate oscillations of a fundamental frequency and to translate oscillations of a higher frequency harmonically related to the fundamental-frequency oscillations. The oscillator also includes a vacuum tube 11 having an envelope 12 enclosing a cathode 13, a control electrode 14, and an anode 15. The anode has a conductive terminal diaphragm 16 which extends exteriorly of the tube envelope 12 transverse the axis of the tube. The control electrode 14 is, of course, electron permeable and also has a conductive terminal diaphragm 17 extending exteriorly of the tube envelope transverse the axis of the tube. The cathode 13 has a terminal sleeve 18 coaxial with the axis of the tube, the sleeve 18 being common to the cathode and to the cathode-heater circuit which includes a conductor 19 supported coaxially of the sleeve 18.

The oscillator includes a coaxial transmission line 20 having an inner conductor 21 thereof coupled to the cathode terminal sleeve 18 and an outer conductor 22 extending through an aperture 23, provided in one wall of the wave guide 10, substantially into the wave guide and electrically closed at the end by the terminal diaphragm 17 of the control electrode. The transmission-line conductor 22 is preferably mechanically and electrically connected to the wave guide 10, as by soldering or brazing around the edges of the aperture 23. The transmission line 20 is short-circuited at its end remote from the terminal diaphragm 17 by an axially movable conductive piston 24 which slides inside of the transmission-line conductor 22 in electrical engagement therewith. The piston 24 also slides over a sleeve 25 in electrical contact therewith, the sleeve 25 being fixedly positioned over a sleeve 26 of insulating material which in turn is fixedly positioned over the transmission-line inner conductor 21, whereby the sleeve 25 is capacitively coupled to the latter. A conductor 27 is supported within, but insulated from, the transmission-line inner conductor 21 and terminates in a connector 28 which engages the end of the heater-circuit conductor 19 to complete the heater circuit to an external energizing source, not shown.

The transmission line 20 normally has substantial coupling to the wave guide 10 by virtue of the inherent capacitance existing between the electrodes of the tube 11. To provide additional coupling, where this is desirable, a probe member 29 is supported in an insulating bushing which is secured in an aperture provided in the outer conductor 22 of the transmission line at a point near the control-electrode diaphragm 17.

The wave guide 10 is provided with an aperture 30, coaxial with the aperture 23, to permit insertion of the tube 11 into operative position. The oscillator includes means for supporting the tube 11 with its electrodes lying within the wave guide and with at least one pair thereof electrically continued by the walls of the wave guide. This means comprises a sheet of insulating material 31 positioned between the anode-terminal diaphragm 16 and the wave guide 10, and capacitively coupling the former to the latter, and the turned-down peripheral portion of the conductive diaphragm 17 which has a close but slidable fit with the inner surface of the end of the transmission-line conductor 22.

A transverse section of the wave guide 10 in the vicinity of the tube 11 essentially comprises the major portion of an inductor which couples the control electrode 14 and the anode 15 and which has in shunt across the ends thereof the inherent capacitance between the anode and control electrode, thus to provide at least a portion of a resonant circuit tuned substantially to resonance at the fundamental frequency of the oscillator. The inductor mentioned also includes the anode-terminal diaphragm 16, the control-electrode terminal diaphragm 17, and the portion of the transmission-line conductor 22 which extends between the wave guide and the diaphragm 17. The oscillator additionally includes capacitive means effective across at least a portion of the wave guide 10 in the vicinity of the vacuum tube 11 for tuning the resonant circuit last mentioned more accurately to resonance at the desired fundamental frequency of the oscillator. This means comprises a condenser member 32 supported at the end of a threaded rod 33 which extends through a threaded aperture 34 provided in a wall of the wave guide 10.

Means is provided for resonating the wave guide 10 to the aforementioned higher-frequency harmonic oscillations in order that the latter may be selected and utilized to the exclusion of the fundamental-frequency oscillations. Referring now to Fig. 2, this means comprises conductive members 35, 36 transverse the wave guide 10 in the interior thereof and adjustably spaced from the vacuum tube 11. The higher-frequency oscillations may be applied from the wave guide 10 to external wave-signal apparatus, not shown, by any suitable means, for example by the use of a probe member 37 which is supported by an insulating bushing 38 extending through one wall of the wave guide 10 at a position relatively removed from the tube 11.

It will be understood that the anode of the vacuum tube 11 is suitably energized from a source of potential, not shown. A resistor, not shown, is connected across the condenser formed by the elements 21, 25 and 26 to complete the direct current path between the control electrode and cathode of the tube.

Considering now the operation of the oscillator just described, the transmission line 20 is initially tuned by adjustment of the piston 24 until it has an effective electrical length of an odd number of quarter-wave lengths at the operating or fundamental frequency of the oscillator. When so tuned, the transmission line 20 has resonant properties, as is well known, and effectively comprises a resonant circuit coupled between the control electrode 14 and cathode 13 of the tube 11. The control electrode 14 and anode 15 are coupled by a resonant circuit formed in large part by the walls of the wave guide 10 acting as an inductor and by the interelectrode capacitance of the anode and control electrode. The oscillator is tuned more exactly to the desired fundamental frequency by movement of the condenser element 32 which provides a small adjustable capacitance in shunt to a portion of the inductor last mentioned.

The resonant circuits thus provided are capacitively coupled by the inherent interelectrode capacitances of tube 11 and by the capacitive

probe 29 where the latter is provided. Oscillations of fundamental frequency are thus generated and oscillatory currents of this frequency flow around the inner surfaces of the walls of the wave guide 10 over a transverse section of the latter in the vicinity of the vacuum tube 11.

The amplitude of the oscillations thus generated is limited by the self-bias potential which the control electrode 14 develops by peak rectification of the generated oscillations. This developed bias is sufficiently large that the anode current of the vacuum tube 11 includes a fundamental-frequency component and a number of harmonic-frequency components.

The dimensions of the wave guide 10 are so proportioned, however, that the fundamental-frequency oscillations thus developed are not propogated longitudinally of the wage guide. On the other hand, the dimensions of the wave guide 10 are such that a desired harmonic-frequency component of the generated oscillations is propagated longitudinally of the wave guide and the conductive members 35 and 36 are so adjusted relative to the vacuum tube 11 that the wave guide selects and translates the desired harmonic-frequency component to the exclusion of other undesired harmonic-frequency components. The desired harmonic-frequency component thus selected is propagated longitudinally of the wave guide 10 to the probe member 37 to induce on the latter waves of voltage and current, whereby the latter operates essentially as an antenna to radiate wave-signal energy of harmonic frequency externally of the wave guide.

It will be apparent from the foregoing description of the invention that the fundamental frequency of the oscillator may be adjusted over a range of values by correlated adjustments of the piston 24 and condenser element 32. The transverse conductive members 35, 36 of the wave guide 10 are, of course, correspondingly adjusted to select any desired harmonic-frequency component of the generated fundamental-frequency oscillations.

The oscillator of the present invention is particularly suited for generating oscillations having a frequency of the order of 3,000 megacycles or higher. For this purpose, and while not limited thereto, illustrative values for the dimensions of the wave guide 10 are as follows:

	Centimeters
Width	4.5
Depth	2
Length	20

While there has been described what is at present considered to be the preferred embodiment of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A high-frequency oscillator comprising, a wave guide having walls with dimensions proportioned substantially to attenuate oscillations of a fundamental frequency and to translate oscillations of higher frequency harmonically related to said fundamental-frequency oscillations, a vacuum tube having input and output electrodes positioned with at least one pair of said electrodes lying within said wave guide and continued electrically by the walls thereof, and means resonant at said fundamental frequency and having substantial regenerative coupling to said wave guide for providing a resonant circuit between another pair of said electrodes to cause said vacuum tube to generate in said wave guide oscillations having said fundamental frequency but including a frequency component of said higher frequency.

2. A high-frequency oscillator comprising, a wave guide having walls with dimensions proportioned substantially to attenuate oscillations of a fundamental frequency and to select and translate oscillations of higher frequency harmonically related to said fundamental-frequency oscillations, a vacuum tube having input and output electrodes positioned with at least one pair of said electrodes lying within said wave guide and continued electrically by the walls thereof, and means resonant at said fundamental frequency and having substantial regenerative coupling to said wave guide for providing a resonant circuit between another pair of said electrodes to cause said vacuum tube to generate in said wave guide oscillations having said fundamental frequency but including a frequency component of said higher frequency.

3. A high-frequency oscillator comprising, a wave guide having walls with dimensions proportioned substantially to attenuate oscillations of a fundamental frequency and to translate oscillations of higher frequency harmonically related to said fundamental-frequency oscillations, means for resonating said wave guide to said higher-frequency oscillations, a vacuum tube having input and output electrodes positioned with at least one pair of said electrodes lying within said wave guide and continued electrically by the walls thereof, and means resonant at said fundamental frequency and having substantial regenerative coupling to said wave guide for providing a resonant circuit between another pair of said electrodes to cause said vacuum tube to generate in said wave guide oscillations having said fundamental frequency but including a frequency component of said higher frequency.

4. A high-frequency oscillator comprising, a wave guide having walls with dimensions proportioned substantially to attenuate oscillations of a fundamental frequency and to translate oscillations of higher frequency harmonically related to said fundamental-frequency oscillations, a conductive member transverse said wave guide in the interior thereof for resonating said wave guide to said higher-frequency oscillations, a vacuum tube having input and output electrodes positioned with at least one pair of said electrodes lying within said wave guide and continued electrically by the walls thereof, and means resonant at said fundamental frequency and having substantial regenerative coupling to said wave guide for providing a resonant circuit between another pair of said electrodes to cause said vacuum tube to generate in said wave guide oscillations having said fundamental frequency but including a frequency component of said higher frequency.

5. A high-frequency oscillator comprising, a wave guide having walls with dimensions proportioned substantially to attenuate oscillations of a fundamental frequency and to translate oscillations of higher frequency harmonically related to said fundamental-frequency oscillations, a vacuum tube having input and output electrodes positioned with at least one pair of said electrodes lying within said wave guide and continued electrically by the walls thereof, means resonant at said fundamental frequency and having substan-

tial regenerative coupling to said wave guide for providing a resonant circuit between another pair of said electrodes to cause said vacuum tube to generate in said wave guide oscillations having said fundamental frequency but including a frequency component of said higher frequency, and at least one conductive member transverse said wave guide in the interior thereof and adjustably spaced from said vacuum tube for resonating said wave guide to said higher-frequency oscillations.

6. A high-frequency oscillator comprising, a wave guide having walls with dimensions proportioned substantially to attenuate oscillations of a fundamental frequency and to translate oscillations of higher frequency harmonically related to said fundamental-frequency oscillations, a vacuum tube having input and output electrodes positioned with at least one pair of said electrodes lying within said wave guide and continued electrically by the walls thereof, and a transmission line coupled between another pair of said electrodes, said line having substantial regenerative coupling to said wave guide and an effective electrical length providing resonance at said fundamental frequency to cause said vacuum tube to generate in said wave guide oscillations having said fundamental frequency but including a frequency component of said higher frequency.

7. A high-frequency oscillator comprising, a wave guide having walls with dimensions proportioned substantially to attenuate oscillations of a fundamental frequency and to translate oscillations of higher frequency harmonically related to said fundamental-frequency oscillations, a vacuum tube having input and output electrodes positioned with at least one pair of said electrodes lying within said wave guide and continued electrically by the walls thereof, a transmission line coupled at one end between another pair of said electrodes and having substantial regenerative coupling to said wave guide, the other end of said transmission line being short-circuited and said line having an effective electrical length equal approximately to an odd number of quarter-wave lengths at said fundamental frequency to cause said vacuum tube to generate in said wave guide oscillations having said fundamental frequency but including a frequency component of said higher frequency.

8. A high-frequency oscillator comprising, a wave guide having walls with dimensions proportioned substantially to attenuate oscillations of a fundamental frequency and to translate oscillations of higher frequency harmonically related to said fundamental-frequency oscillations, a vacuum tube having input and output electrodes including a common electrode positioned with at least one pair of said electrodes lying within said wave guide and continued electrically by the walls thereof, a coaxial transmission line coupled to another pair of said electrodes including said common electrode and having the outer conductor thereof electrically coupled to said wave guide and to said common electrode, said line having substantial regenerative coupling to said wave guide and an effective electrical length providing resonance at said fundamental frequency to cause said vacuum tube to generate in said wave guide oscillations having said fundamental frequency but including a frequency component of said higher frequency.

9. A high-frequency oscillator comprising, a wave guide having walls with dimensions proportioned substantially to attenuate oscillations of a fundamental frequency and to translate oscillations of higher frequency harmonically related to said fundamental-frequency oscillations, a vacuum tube having input and output electrodes including a common electrode positioned with at least one pair of said electrodes lying within said wave guide and continued electrically by the walls thereof, a coaxial transmission line coupled to another pair of said electrodes including said common electrode and having the outer conductor thereof extending substantially into said wave guide in electrical engagement therewith and coupled to said common electrode, said line having substantial regenerative coupling to said wave guide and an effective electrical length providing resonance at said fundamental frequency to cause said vacuum tube to generate in said wave guide oscillations having said fundamental frequency but including a frequency component of said higher frequency.

10. A high-frequency oscillator comprising, a wave guide having walls with dimensions proportioned substantially to attenuate oscillations of a fundamental frequency and to translate oscillations of higher frequency harmonically related to said fundamental-frequency oscillations, a vacuum tube having an envelope enclosing a cathode, a control electrode and an anode, said anode and control electrode each having a conductive terminal diaphragm extending exteriorly of said envelope transverse the axis of said tube, means supporting said tube with said anode and control electrode lying within said wave guide and said anode diaphragm coupled thereto, and a coaxial transmission line coupled to said cathode and control electrode with the outer conductor of said line electrically coupled to said control-electrode diaphragm and to said wave guide electrically to continue said control electrode by the walls of said wave guide, said transmission line being resonant at said fundamental frequency and having substantial regenerative coupling to said wave guide to cause said vacuum tube to generate in said wave guide oscillations having said fundamental frequency but including a frequency component of said higher frequency.

11. A high-frequency oscillator comprising, a wave guide having walls with dimensions proportioned substantially to attenuate oscillations of a fundamental frequency and to translate oscillations of higher frequency harmonically related to said fundamental-frequency oscillations, a vacuum tube having an envelope enclosing a cathode, a control electrode and an anode, said anode and control electrode each having a terminal diaphragm extending exteriorly of said envelope transverse the axis of said tube, means supporting said tube with said anode and control electrode lying within said wave guide and said anode diaphragm coupled thereto, and a coaxial transmission line coupled to said cathode and control electrode with the outer conductor of said line electrically coupled to said wave guide and electrically closed at the end by said control-electrode diaphragm, whereby said anode and control electrodes are continued electrically by the walls of said wave guide, said transmission line being resonant at said fundamental frequency and having substantial regenerative coupling to said wave guide to cause said vacuum tube to generate in said wave guide oscillations having said fundamental frequency but including a frequency component of higher frequency.

12. A high - frequency oscillator comprising, a wave guide having walls with dimensions proportioned substantially to attenuate oscillations of a

fundamental frequency and to translate oscillations of higher frequency harmonically related to said fundamental-frequency oscillations, a vacuum tube having an evacuated envelope and including pairs of input and output electrodes at least one of which pairs is extended outside of said envelope by individual conductive diaphragm members transverse the axis of said tube, means supporting said tube with at least said pair of electrodes lying within said wave guide and said diaphragm members electrically coupled to individual opposing areas of said wave guide, whereby said pair of electrodes are continued electrically by the walls of said wave guide, and means resonant at said fundamental frequency and having substantial regenerative coupling to said wave guide for providing a resonant circuit between another pair of said electrodes to cause said vacuum tube to generate in said wave guide oscillations having said fundamental frequency but including a frequency component of said higher frequency.

13. A high - frequency oscillator comprising, a wave guide having walls with dimensions proportioned substantially to attenuate oscillations of a fundamental frequency and to translate oscillations of higher frequency harmonically related to said fundamental-frequency oscillations, a vacuum tube having an envelope enclosing a cathode, a control electrode and an anode, said anode and control electrode each having a terminal diaphragm extending exteriorly of said envelope transverse the axis of said tube and said cathode having a terminal sleeve coaxial with the axis of said tube, means supporting said tube with said anode and control electrode lying within said wave guide and said anode diaphragm coupled thereto, and a coaxial transmission line having the inner conductor thereof coupled to said cathode sleeve and the outer conductor thereof coupled to said control electrode diaphragm and to said wave guide, whereby said anode and control electrode are continued electrically by the walls of said wave guide, said line being resonant at said fundamental frequency and having substantial regenerative coupling to said wave guide to cause said vacuum tube to generate in said wave guide oscillations having said fundamental frequency but including a frequency component of said higher frequency.

14. A high - frequency oscillator comprising, a wave guide having walls with dimensions proportioned substantially to attenuate oscillations of a fundamental frequency and to translate oscillations of higher frequency harmonically related to said fundamental-frequency oscillations, a vacuum tube having input and output electrodes positioned with at least one pair of said electrodes lying within said wave guide and continued electrically by the walls thereof to provide a first resonant circuit, means resonant at said fundamental frequency and having substantial regenerative coupling to said wave guide for providing a second resonant circuit coupled between another pair of said electrodes, and capacitive means effective across at least a portion of said wave guide in the vicinity of said vacuum tube for tuning said oscillator more accurately to resonance at said fundamental frequency to cause said vacuum tube to generate in said wave guide oscillations having said fundamental frequency but including a frequency component of said higher frequency.

15. A high - frequency oscillator comprising, a wave guide having walls with dimensions proportioned substantially to attenuate oscillations of a fundamental frequency and to translate oscillations of higher frequency harmonically related to said fundamental-frequency oscillations, a vacuum tube having input and output electrodes positioned with at least one pair of said electrodes lying within said wave guide and continued electrically by the walls thereof, means resonant at said fundamental frequency for providing a resonant circuit between another pair of said electrodes, and means for regeneratively coupling energy from said wave guide to said last-named means to cause said vacuum tube to generate in said wave guide oscillations having said fundamental frequency but including a frequency component of said higher frequency.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,153,728	Southworth	Apr. 11, 1939
2,169,396	Samuel	Aug. 15, 1939
2,281,935	Hansen et al.	May 5, 1942
2,305,883	Litton	Dec. 22, 1942
2,368,031	Llewellyn	Jan. 23, 1945
2,372,193	Fisk	Mar. 27, 1945
2,400,753	Haeff	May 21, 1946
2,404,113	Wagner	July 16, 1946