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HIGH-FREQUENCY TUBE STRUCTURE

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Fig. 1

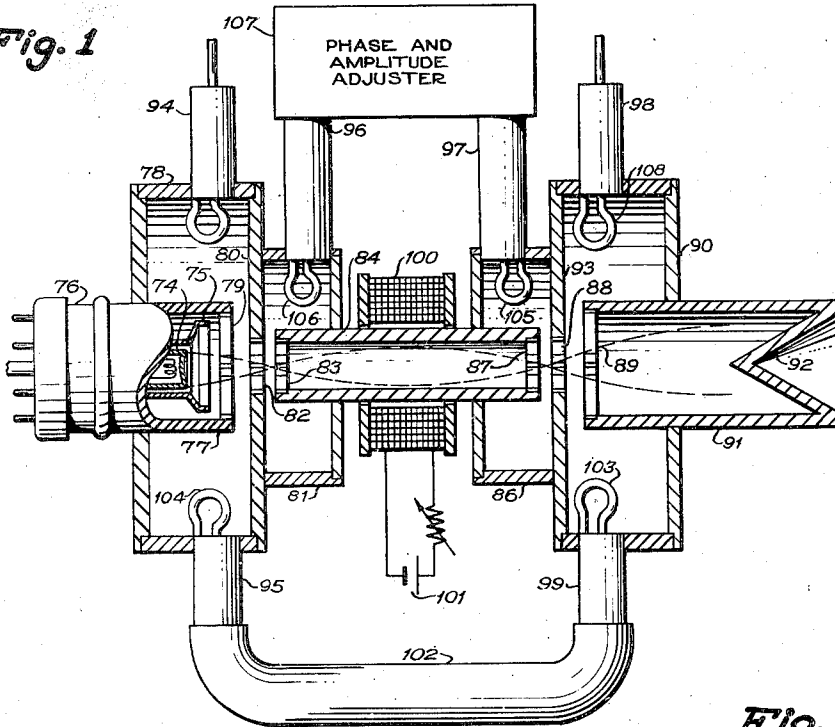


Fig. 2

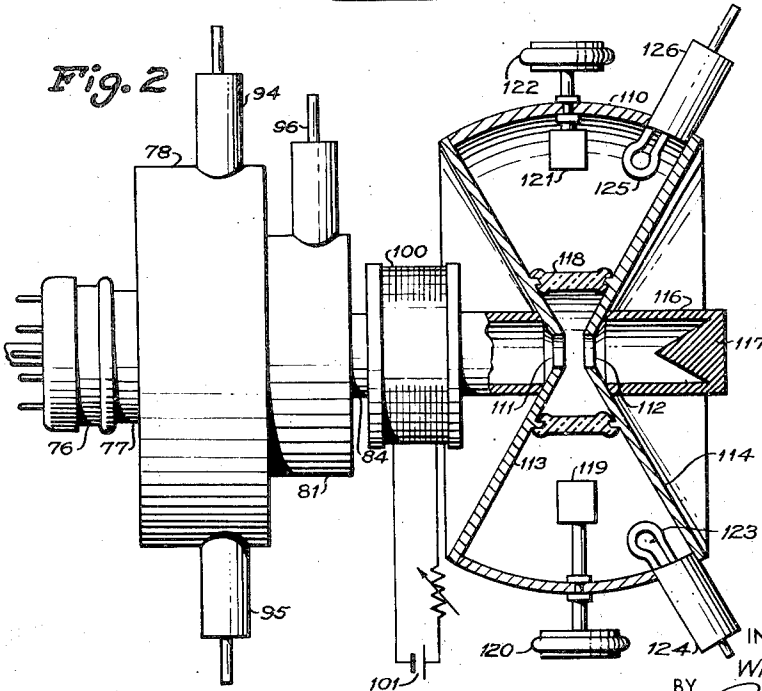


Fig. 3

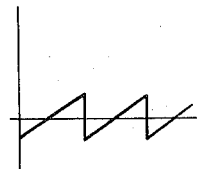


Fig. 4



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HIGH-FREQUENCY TUBE STRUCTURE

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ruary 17, 1945, Serial No. 578,394

13 Claims. (Cl. 315-6)

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This invention relates, generally, to ultra-high-frequency apparatus operable at wavelengths of the order of one hundred to one centimeter, corresponding to frequencies from 300 to 30,000 megacycles per second, and is more particularly concerned with modifications and improvements of electron discharge devices of the type disclosed in Patent No. 2,242,275, issued May 20, 1941, in the name of Russell H. Varian, the purpose of these modifications and improvements being to increase the overall efficiency of such devices.

The present application is a division of application Serial No. 423,930 for High frequency tube structure, filed December 22, 1941, now Patent No. 2,445,811, issued July 27, 1948.

The device of the above-mentioned Varian patent is therein shown to consist of means providing an electron beam arranged to traverse alternating electric fields of hollow resonant means, thereby causing velocity changes of the electrons and subsequent bunching thereof, the bunches acting to maintain an oscillating ultra high frequency field in the resonant means.

The principal object of the present invention is to provide a novel ultra high frequency tube structure of enhanced efficiency, obtained by effecting more complete bunching of the electrons of the electron stream, and by improving the wave form of the buncher apparatus.

A further object is to provide an electron beam velocity modulating device from which outputs of a plurality of different frequencies may be obtained.

Another object of the invention is the provision of resonant cavity means operating at fundamental and harmonic frequencies for producing more complete grouping of the electrons of the stream to thus effect more complete and efficient conversion of direct current energy to high frequency alternating current energy.

Still another object of the present invention is to provide improved apparatus for producing velocity-grouping of electrons of an electron beam, by providing non-sinusoidal velocity modulation thereof.

Yet a further object is to provide improved velocity modulation electron discharge apparatus having an electron stream modulated non-sinusoidally, such as produced by simultaneous velocity modulation at a fundamental frequency and a harmonic thereof.

Other objects and advantages will become apparent from the specification, taken in connection with the accompanying drawings wherein the invention is embodied in concrete form.

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In the drawings,

Fig. 1 is a partial cross-section elevation view of one form of the invention.

Fig. 2 is a partial elevation cross-section view of a modified form of Fig. 1.

Figs. 3 and 4 are explanatory graphs.

Similar characters of reference are used in all of the above figures to indicate corresponding parts.

As disclosed in Varian Patent No. 2,242,275, a conventional velocity modulation electron discharge device comprises an electron gun for producing a uniform velocity electron stream which is projected through an input or "buncher" cavity resonator which alternately accelerates and decelerates (thus "velocity modulating") the electrons. These velocity-modulated electrons continue in a field-free drift space where the faster electrons overtake the slower ones, resulting in "bunching" or "velocity-grouping" of the electrons. This bunched or grouped stream is an electron current having an ultra-high-frequency component (and harmonics thereof) superposed upon a direct current component. This stream passes through a second output or "catcher" resonator and delivers amplified energy of this frequency (or harmonics thereof) to this second resonator. This energy is available for supplying any load, and part of it may be fed back to supply the "buncher" resonator to sustain the oscillations in the catcher resonator.

The most desirable wave form for the electron beam current entering the energy-extracting resonator of such an electron beam velocity modulation device is a delta function of infinite height and of infinitely narrow width. The term "delta function" is defined in P. A. M. Dirac's "Principles of Quantum Mechanics" (1937) at page 72 and as used herein means a function having a finite area under its curve while being infinitely narrow. The velocity modulating or buncher resonator, in order to produce a wave form approaching the desired one, must have an electromagnetic field which changes linearly in time, such as shown in Fig. 3. Such a type of velocity modulation produces a desirable sharply pulsed beam at the entrance grid of the second resonator which approaches the desired peaked delta function, shown in Fig. 4, thereby obtaining improved operating efficiencies. The device shown in Fig. 1 operates according to such a principle.

Referring to Fig. 1, there is shown a concave electron emitter surface 74 surrounded by a co-operating focusing ring 75, supported in glass

end bell 76. The entire cathode structure is mounted in conducting cylinder 77 which forms the reentrant portion of a hollow cavity resonator 78 and also supports accelerating grid 79 directly in front of emitter 74. The wall 80 of resonator 78 carries the opposite grid 82 and serves as the common wall between resonator 78 and a resonator 81, the resonator 81 being tuned to a harmonic of the resonant frequency of resonator 78, preferably the second or third harmonic. A cylindrical tube 84 forms the reentrant portion of resonator 81 and supports grid 83 opposite to grid 82. Tube 84 forms the drift tube and constitutes the reentrant portion of a resonator 86 and supports a grid 87 in its end opposite grid 88 in the common wall 93 between resonator 86 and another resonator 90. Resonator 86 is tuned to the same harmonic frequency as resonator 81, while resonator 90 is tuned to the same resonant frequency as resonator 78. A tube 91 forms the reentrant portion of resonator 90, supporting a grid structure 89 adjacent to grid 88 of wall 93. Tube 91 may be terminated in reentrant conical end piece 92, which may serve to direct secondary electrons (emitted when high velocity electrons strike its surface) toward the outer cylindrical wall of member 91, thereby collecting such secondaries and preventing their harmful interaction with the resonators. Resonator 78 may be supplied with concentric line elements or terminal posts 94, 95, resonator 81 with terminal post 96, resonator 86 with terminal post 97, and resonator 90 with terminal posts 98 and 99, in the well-known manner.

Focusing coil 100 may be supplied by a controllable direct current from battery 101 to cooperate with the focusing cathode structure 74, 75, to bring the electron beam to a focus in the vicinity of grid 82 and again near grid 88.

Electrons from emitter surface 74 are accelerated by a direct voltage applied between surface 74 and grid 79 and are focused by shield 75 to an approximate focus at grid 82. If there is assumed to be a high frequency electric field oscillating between grids 79 and 80 of resonator 78, the electron beam suffers recurrent changes in electron velocity, that is, is velocity modulated; and, in passing on through drift tube 84, becomes grouped or density modulated. These grouped electrons release high frequency energy on again coming to a focus near grid 88, generating and maintaining an oscillating electromagnetic field in resonator 90. Energy to maintain oscillations in resonator 78 may then be coupled back from resonator 90 through concentric line elements 99, 102, and 95, cooperating with coupling loops 103 and 104.

As disclosed in prior Hansen and Varian Patent No. 2,281,935, for Modulation system, granted May 5, 1942, the electron beam current entering resonator 90 has many harmonic components, so that if resonator 86 has a natural or resonant frequency equal to a harmonic of the resonant frequency of resonators 78 and 90, it may also be excited into electromagnetic oscillation at this harmonic frequency by these same electron groups. A portion of this harmonic energy may be fed to resonator 81 by means of coupling loops 105, line 97, phase and amplitude adjusting element 107, line 96, and coupling loop 106. Upon proper adjustment of element 107, resonator 81 may be excited so that the combined effects of the oscillating electric fields in resonators 78 and 81 is to produce a resultant action on the beam from cathode 74 which approximates that which

would be produced by the desired saw tooth wave form of Fig. 3, as is well known in the art of Fourier analysis. The system is thus self-oscillatory, operating with considerably enhanced efficiency, and with output ultra high frequency power removable by means of coupling loop 108 and concentric line element 98.

Additional concentric lines 97 may be coupled to the harmonic field inside resonator 86, so that the device may have an output of two differing frequencies, with no necessity for interposing filter means for separating them. The device may also be used as an amplifier, when elements 104, 95, 102, 99 and 103 are omitted, energy being introduced to the amplifier by coaxial line 94 and removed by means of line 98.

It is evident to one skilled in the art that resonators 81 and 86 may be made resonant to any desirable harmonic of the frequency at which resonators 78 and 90 operate. It is also evident that, in addition to the harmonic resonators 81 and 86, there may be supplied other and additional harmonic resonators attached to each fundamental resonator 78, 90.

The device of Fig. 2 operates similarly to that shown in Fig. 1. In this device resonators 86 and 90 are replaced by a single resonator 110 of spherical segment shape having opposed reentrant cone-shaped poles, such a device having been previously described in prior application Serial No. 416,170, filed October 23, 1941, now Patent No. 2,425,738 issued August 19, 1947, in the names of William W. Hansen, John R. Woodyard, Sigurd F. Varian and Russell H. Varian. As explained therein, a resonator such as device 110 is capable of having an oscillating electromagnetic field maintained in it simultaneously at a fundamental frequency and at an odd harmonic frequency. Energy at each of these frequencies may be extracted independently of the other frequency by properly positioned coupling elements, such as loops 123 and 125. Resonator 110 is attached to drift tube 84 so that apertures 111 and 112 in the cone-shaped reentrant portions 113 and 114, respectively, of resonator 110 are spaced approximately on each side of the focal spot produced in the electron beam by coil 100. Tube 116 is attached to cone 114 opposite tube 84, and has its end opposite aperture 112 closed by reentrant conical portion 117, which serves to reflect secondary electrons (produced when the primary electron beam strikes cone 92) toward the walls of tube 116 rather than back into resonator 110. Glass tube 118 is provided concentric to tubes 84 and 116 to provide continuity to the vacuum envelope, and is placed where it has the least effect upon the two oscillating electric fields. Tube 118 may preferably be placed at a position of zero electric field for the harmonic field.

As shown in the aforementioned prior Patent No. 2,425,738, the two oscillating fields may be tuned independently by placing a paddle 119 rotatable by knob 120 in a position such as shown in the drawings, its position being that which disturbs the fundamental electric field and not the harmonic field. Similarly, paddle 121, rotatable by knob 122, is placed so that it does not disturb the fundamental electric field, but does alter the harmonic field. In this manner, the fundamental and harmonic fields may be independently tuned.

The device may be made to operate as an oscillator by coupling loop 123 to resonator 78 through concentric line posts 124 and 95. Resonator 78, being tuned to the fundamental frequency of res-

onator 110, rejects the harmonic frequency. Harmonic energy may be coupled back to resonator 81 through concentric lines 126 and 96, as in Fig. 1. Resonator 81, being tuned to the harmonic frequency of resonator 110, rejects the fundamental frequency. Phase and amplitude adjusting devices may be used between lines 124, 95 and 126, 96, if desirable. In use of the device as an amplifier, the connecting line between concentric lines 124 and 95 is omitted, the energy to be amplified being introduced through concentric line 95 and removed through line 124.

It is evident to one skilled in the art that energy of both fundamental and harmonic frequencies may be removed as shown in the aforementioned Patent No. 2,425,738 from resonator 110. It is also evident that resonators 78 and 81 may be replaced by a single resonator of the same type as resonator 110.

In both Figs. 1 and 2, the focussing coil 100 may be omitted, in which case the cathode 74 and focussing electrode 75 are formed in well-known manner so as to provide a beam of electrons travelling in parallel paths.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A high frequency tube structure comprising means for producing an electron stream, means including a plurality of hollow resonators along the path of said stream for effecting recurrent bunching of the electrons of the stream, and a plurality of hollow output resonators disposed in the path of the stream and tuned to differing frequencies for abstracting energy from the stream.

2. A high frequency tube structure comprising means for producing an electron stream, plural resonator means along the path of said stream for effecting recurrent bunching of the electrons of the stream at fundamental and harmonic frequencies, an additional resonator positioned in the path of said bunched stream for absorbing energy therefrom, said additional resonator having two simultaneous modes of oscillation at frequencies corresponding to the fundamental frequency of said bunched beam and the harmonic thereof, and means coupled to said additional resonator for extracting energy from said additional resonator at said fundamental and harmonic frequencies.

3. High frequency tube structure comprising means for producing an electron stream, a first cavity resonator tuned to a predetermined frequency and positioned along the path of said stream in energy-exchanging relation thereto, a second cavity resonator positioned along said path in energy-exchanging relation to said stream and tuned substantially to a harmonic of said predetermined frequency, a third cavity resonator positioned along said path in energy-exchanging relation to said stream and also tuned substantially to said harmonic frequency, and means coupling said second and third resonators together.

4. High frequency tube structure comprising means for producing an electron stream, a first cavity resonator tuned to a predetermined frequency and positioned along the path of said

stream in energy-exchanging relation thereto, a second cavity resonator tuned substantially to a harmonic of said predetermined frequency and positioned along said path in energy-exchanging relation to said stream, a third cavity resonator tuned substantially to said predetermined frequency and positioned along said path in energy-exchanging relation to said stream, and means coupling said first and third resonators together.

5. High frequency tube structure as in claim 3, further including a fourth cavity resonator tuned substantially to said predetermined frequency and positioned along said path in energy-exchanging relation to said stream, and means defining a field-free drift space between said second and third resonators, whereby said first and second resonators serve to velocity modulate the electrons of said stream in non-sinusoidal fashion, and said third and fourth resonators serve to extract high frequency energy from said stream at different harmonically related frequencies.

6. High frequency apparatus comprising means for producing an electron stream, means along the path of said stream for velocity modulating said stream at a fundamental frequency and at a harmonic thereof, means along said stream path for extracting energy of said harmonic frequency from said stream, and means coupling said extracting means to said modulating means.

7. High frequency apparatus comprising means for producing an electron stream, means along the path of said stream for velocity modulating said stream at a fundamental frequency and at a harmonic thereof, means along said stream path for extracting energy of said fundamental frequency from said stream, and means coupling said extracting means to said modulating means.

8. High frequency tube structure comprising a source of electrons, three electron-permeable electrodes aligned with said source and located close to one another to provide two gaps adapted to be successively traversed by the electrons from said source, a first tuned circuit coupled between the center one of said electrodes and one outermost electrode, a second tuned circuit coupled between said center electrode and the other outer electrode, one of said circuits being tuned to a fundamental frequency and the other to a frequency which is substantially a harmonic of said fundamental frequency, and a drift-space-defining member surrounding the path of said electrons on the side of said electrodes opposite from said electron source.

9. Tube structure as in claim 8 wherein said resonant circuits are provided by cavity resonators.

10. Tube structure as in claim 9 wherein means are provided for exciting said two resonators at said fundamental and harmonic frequencies.

11. Tube structure as in claim 8 further comprising output circuit means along the path of said electrons adjacent the other end of said drift-space-defining member.

12. Tube structure as in claim 11 wherein said output means are adapted to abstract both fundamental and harmonic frequencies from said electron stream.

13. Tube structure as in claim 12 wherein said output means are provided by cavity resonator means.

WILLIAM W. HANSEN.

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