

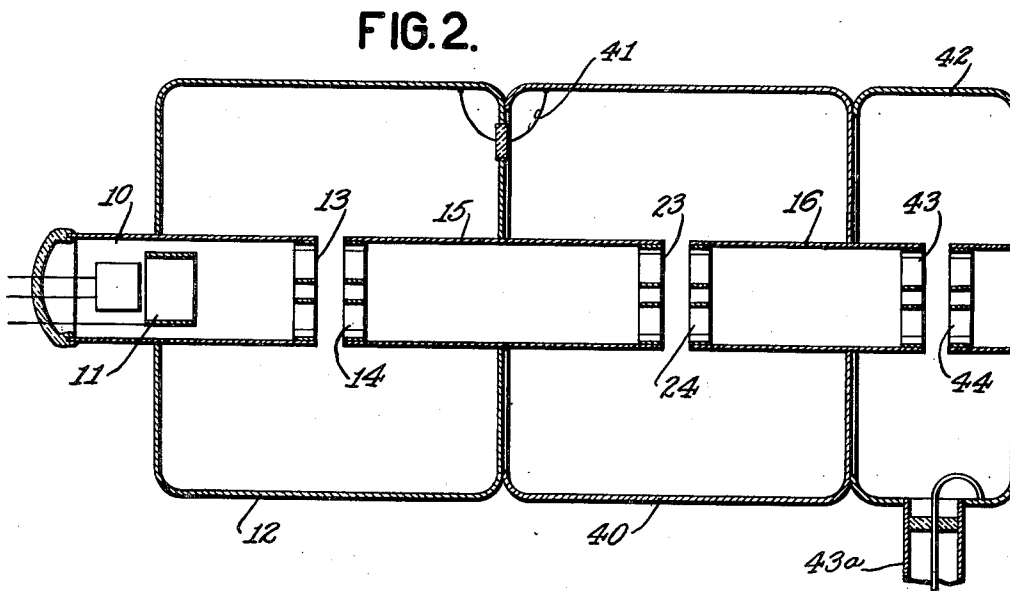
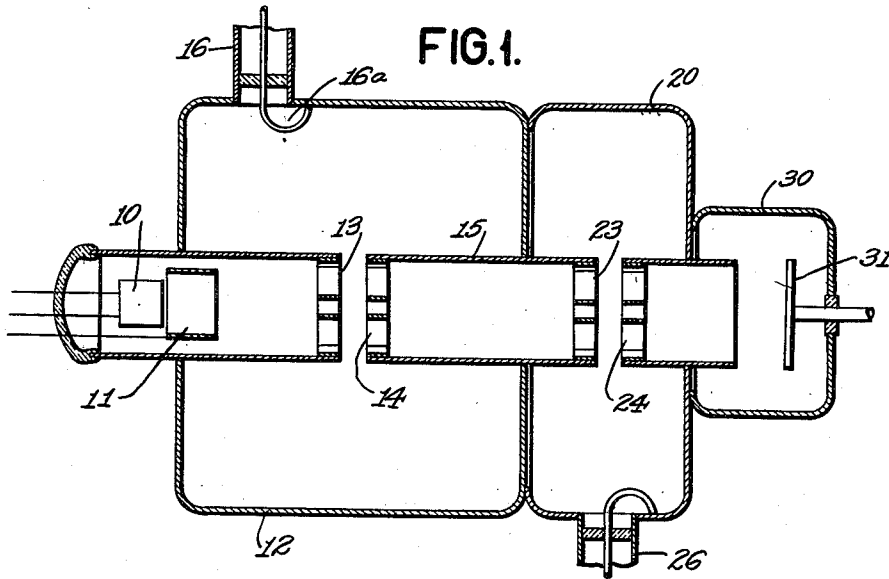
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FREQUENCY MULTIPLIER

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FREQUENCY MULTIPLIER

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This invention relates to ultra high frequency multipliers and more particularly to frequency multipliers using the principles of electron velocity modulation.

Certain types of amplifiers and oscillation generators are known in which a stream of electrons is subjected to a force which modifies the velocity of certain electrons in the stream. The electrons are then allowed to become bunched and energy is extracted from the electron stream by means of a resonant circuit tuned to a frequency represented by the electron bunches.

It is a principal object of my invention to provide a frequency multiplier in which electron grouping or bunching is achieved by velocity modulation of an electron stream.

According to one feature of my invention, the frequency multiplication is accomplished by extracting energy by means of a resonant circuit tuned to a harmonic of the frequency represented by the electron grouping from an electron stream in which the electrons have been previously bunched, as outlined above. This resonant circuit is tuned preferably to a low harmonic, for example, the third harmonic, and is excited by shock excitation by the electron bunches once every third oscillation thereof, when the third harmonic is used. The resonant circuit is made to have a very low loss or high Q, and accordingly will sustain oscillations during the periods between the shock excitations.

According to another feature of my invention, I provide an oscillation generator operating at a particular high frequency in accordance with the velocity modulation principles, and provide a harmonically tuned circuit at the output thereof, energized by shock excitation from said generator to produce frequency multiplied waves.

A better understanding of my invention and the various features and objects thereof, may be had from the following description taken in connection with the accompanying drawing, in which:

Fig. 1 illustrates a preferred form of frequency multiplier in accordance with my invention; and

Fig. 2 illustrates a modification of my invention to directly produce the desired oscillation energy.

In Fig. 1 is shown a vacuum tube arrangement having a cathode 10 for emitting electrons, and an accelerator electrode 11 for causing the electrons emitted from said cathode to form into an accelerated electron beam. The electrons in said beam pass through a first resonant circuit 12. In

resonant circuit 12 are provided grids 13, 14, which serve to modify the velocity of some of the electrons in the beam in accordance with the oscillation frequency of resonant circuit 12. This circuit 12 is referred to as a velocity modulator and causes the electrons to become bunched or grouped upon passage through tube 15, due to the change in relative velocity. These bunches of electrons are interspersed with spaces wherein the electrons are widely spaced, the distribution being generally in a fundamental wave form rich in harmonics.

On the output side of tube 15 is coupled a second resonant circuit 20. This resonant circuit 20 is tuned to a frequency harmonically related to the fundamental frequency of circuit 12. The two grids 23, 24 are provided in circuit 20 which serves to extract energy from the grouped or bunched electrons passing therethrough. Since circuit 20 extracts energy from the electron beam, this circuit is referred to as the extractor circuit. Energy at the fundamental frequency is fed into a resonant circuit 12 over an input line 16 having a coupling loop 16a, and the harmonic energy produced in circuit 20 is applied to some useful purpose over output circuit 26. If desired, circuit 20 may constitute a closed chamber so that the electrons are decelerated and collected upon grid 24. However, in order to enhance the efficiency of the system and to reduce the heating of the resonant circuit, I prefer to provide an enclosure 30 beyond circuit 20, which the electrons pass after traversing the extractor circuit. In enclosure 30 is provided an electrode 31 which is preferably maintained at a positive potential just sufficient to attract all of the electrons thereto. If the heating of the circuit becomes pronounced, additional cooling means may be provided. However, since such cooling means constitute no part of the present invention and are known in themselves, no disclosure thereof is made in this application.

In operation, the energy to be multiplied is introduced into first resonant circuit 12 by means of line 16. This energy excites oscillations in resonant circuit 12 so that electrons passing between grids 13 and 14 are given different accelerations. The resulting change in velocity may be relatively small. The electron beam, however, passes on through tube 15, and this tube is made sufficiently long so that alternate concentration and rarefaction groups of the electrons in the beam are formed. These concentrations or bunches then serve to excite oscillations in circuit 20 because of their harmonic

content, the frequency of which is determined by the tuning of the circuit, by impact or shock excitation. Since circuit 20 is an extremely low loss circuit, the oscillations so induced will be sustained over the period until the next fundamental impulse is applied. Preferably circuit 20 is tuned to a low harmonic of the fundamental frequency, such as the third harmonic. Accordingly, the energy input at 16 may be extracted at 26 at a harmonic frequency of the fundamental input energy. All of the energy produced by the group of the electrons in the beam by the action of input energy from 16 is not transformed into harmonic energy. The additional energy is absorbed at electrode 31.

In Fig. 1 I have disclosed an embodiment of my invention wherein the harmonic frequency is generated from a fundamental frequency fed into the circuit. In the modification illustrated in Fig. 2 is shown an arrangement wherein the entire energy is generated in a single tube structure. In this figure, a cathode 10 and accelerator electrode 11 are provided, corresponding to the same elements of Fig. 1. Also, a first resonant chamber 12, together with bunching grids 13, 14 are provided. The beam of electrons after being modified in velocity by velocity modulator circuit 12, then passes on into a circuit 40. This circuit 40 may be termed a first extractor circuit and is tuned to the same frequency as resonant circuit 12. The electrons which have been bunched while traveling through tube 15 have energy extracted therefrom at grids 23, 24. Accordingly, circuit 40 will build up oscillations at the same fundamental frequency as circuit 12. In order that these oscillations may be sustained, a feedback loop 41 is provided interconnecting chambers 12 and 40. Accordingly, the resonant circuits 12 and 40, together with their other elements constitute an oscillation generator producing energy at the fundamental frequency. The electron beam is then passed through a second drift tube 16 which is made of sufficient length to allow a grouping of the electrons therein.

A third resonant circuit 42 corresponding to circuit 20 of Fig. 1 is provided and is tuned to a harmonic of the fundamental frequency generated in the oscillation generator. A pair of grid electrodes 43, 44 are provided in circuit 42 for extracting energy from the grouped electrons passed therethrough from circuit 40. Resonant circuit 42 serves as a second extractor circuit from extracting energy from the grouped electrons. Thus, harmonic oscillations are produced in circuit 42 by shock excitation, as explained above. Energy may then be fed from circuit 42 over transmission line 43a to any desired load.

While I have disclosed above particular embodiments of my invention, it is to be distinctly understood that these illustrations are submitted merely by way of example. Other modifications will occur to those skilled in the art. For instance, instead of terminating circuit 42 in the manner shown in Fig. 2, an additional enclosure with a target electrode similar to 31 of Fig. 1 may be supplied if desired. Furthermore, although it is preferable to use closed chamber resonant circuits because of the extremely low loss or high Q of such circuits, any type of resonant circuit may be used so long as the circuits are arranged to properly modify and utilize the velocity variations caused in the electron beam. What I consider as my invention

and desire to secure protection upon is embodied in the accompanying claims.

What I claim is:

1. An electron discharge tube of the velocity modulated electron stream type comprising a first electrode, a second electrode, means for projecting a stream of electrons along a path from said first electrode to said second electrode, a velocity modulation circuit resonant to a first frequency located in said path adjacent to the first electrode, and an extractor circuit resonant to a second frequency higher than said first frequency, located in said path between said velocity modulation circuit and said second electrode.
2. A velocity modulating discharge tube comprising means for producing a stream of electrons along a path, means forming a velocity modulating resonant chamber tuned to a given frequency, in partial intercepting relation with said path, and means forming a resonant extracting chamber in intercepting relation with said path, tuned to a frequency higher than and positioned beyond said velocity modulating resonant chamber.
3. A velocity modulation discharge tube comprising means for producing a stream of electrons, a velocity modulation circuit tuned to a given frequency, a first extractor circuit tuned to said given frequency, a second extractor circuit tuned to a different frequency, coupling means interconnecting said velocity modulation circuit and said first extractor circuit and an output connection from said second extractor circuit.
4. A velocity modulating discharge tube comprising means for producing a stream of electrons along a path, means forming a velocity modulating resonant chamber tuned to a given frequency, in partial intercepting relation with said path, and means forming a resonant extracting chamber in intercepting relation with said path, said resonant extracting chamber being positioned beyond said velocity modulating resonant chamber and tuned to an odd harmonic of said given frequency.
5. A velocity modulation discharge tube comprising a velocity modulation circuit, a first extractor circuit and a second extractor circuit, means for directing a stream of electrons through said circuits in succession, said velocity modulation circuit and said first extractor circuit being tuned to the same given frequency and said second extractor circuit being tuned to an odd harmonic of said given frequency, means for feeding back energy from said first extractor circuit to said velocity modulation circuit to cause a production of oscillations, and means for extracting energy from said second extractor circuit.
6. A frequency multiplier comprising a velocity modulating discharge tube having means forming a first resonant chamber tuned to a given frequency, means for producing a stream of electrons along a path through said first resonant chamber, means coupled with said first resonant chamber and in partial intercepting relation with said path for modifying the velocity of some of the electrons in said stream, means including a drift tube in alignment with said path for allowing the electrons modified in velocity to form bunches in said stream, means forming a second resonant chamber of low loss characteristics coupled to said drift tube and tuned to a harmonic of said fundamental frequency, and means in said second resonant chamber for extracting energy from said bunched electron stream to produce oscillations in said second chamber at its resonant frequency.

7. Means for producing ultra high frequency comprising a source of electrons for producing an electron stream, a first resonant circuit tuned to a particular frequency, means coupled with said first resonant circuit for modifying the velocity of electrons in said stream, drift-tube means allowing the electrons modified in velocity to form into groups, a second resonant circuit tuned to said particular frequency for extracting energy from said grouped electrons, means intercoupling said first resonant circuit and said second resonant circuit to sustain oscillations at said particular frequency, a third resonant circuit of low loss characteristics tuned to a harmonic of said particular frequency, drift-tube means allowing said grouped electrons to pass to said third circuit from said second circuit, means in said third circuit for extracting energy from said grouped electrons to

excited oscillations therein at said harmonic, and output means coupled with said third resonant circuit for utilizing the harmonic frequency energy.

8. Electron discharge apparatus comprising means forming a resonant chamber tuned to a frequency to be generated, means for producing a stream of electrons along a path, means in partial intercepting relation with said path for grouping electrons from said stream into a stream of grouped electrons in accordance with a frequency lower than that of said resonant chamber, and means disposed intermediate said grouping means and said resonant chamber for projecting said stream of grouped electrons past said resonant chamber.

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