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TUBE ARRANGEMENT FOR FREQUENCY DOUBLING

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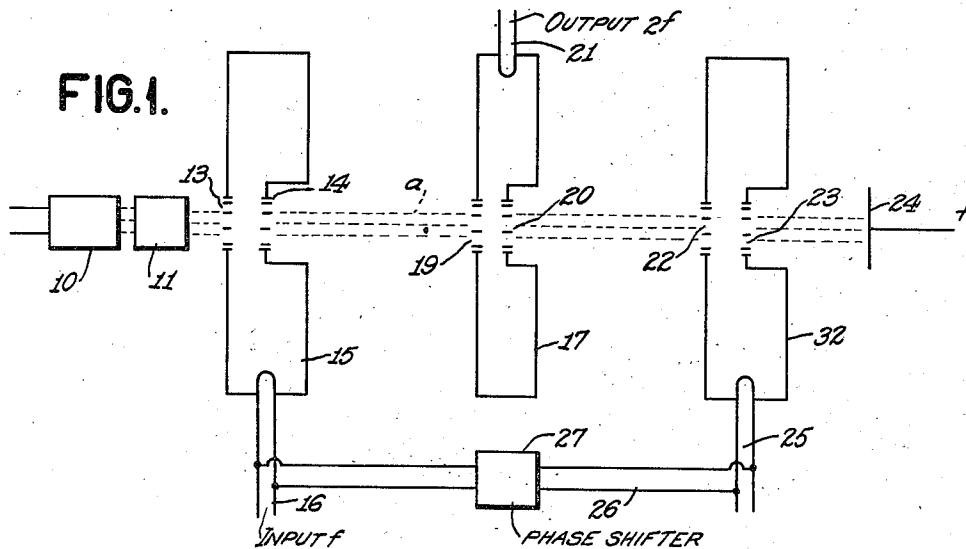


FIG. 1A.

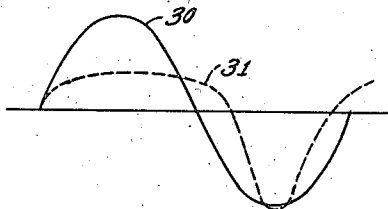
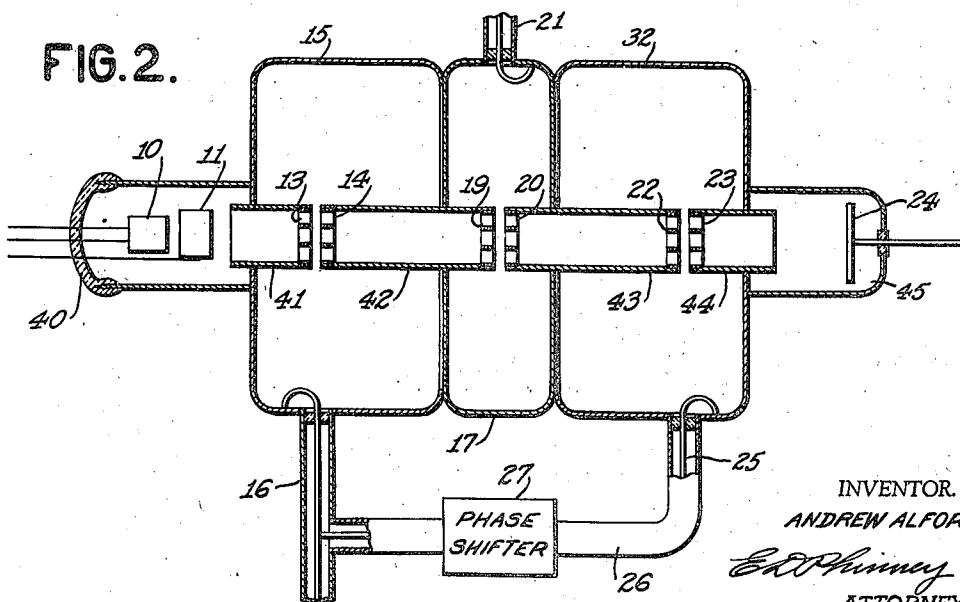


FIG. 2.



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TUBE ARRANGEMENT FOR FREQUENCY DOUBLING

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4 Claims. (Cl. 315-6)

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This invention relates to frequency doubling devices, and more particularly to electron tube arrangements operating on the principle of velocity modulation for producing frequency multiplication.

In a known form of circuit a beam or stream of electrons is modified in velocity at a given point. The electrons of the beam are then permitted to form into bunches or groups due to the change in velocity by traveling a given distance. By properly choosing this drift distance the electrons reach a point of maximum bunching or grouping. A resonant circuit is coupled to extract the energy from the bunched electrons. This resonant circuit is tuned to the fundamental frequency which corresponds substantially with the grouping of the electron bunches.

According to one feature of my invention I provide a tube circuit with a velocity modulating circuit similar to those of the prior art for modulating the beam at a given fundamental frequency. However, instead of providing a second resonant circuit at the optimum spacing for operation at the fundamental frequency, I provide a drift distance greater than this spacing so that the electrons within the bunches tend to spread, because of the combined effect of velocity differences and the inter-electron repulsion. Consequently the bunchings and rarefactions are no longer substantially symmetrical, since the additional effect of electron repulsion tends to spread the bunches to an extent greater than the increase in density of the electrons in the rarefied portions of the beam. Consequently, the wave form is such as to be rich in even harmonics. I then provide a tuned circuit to an even harmonic, preferably the second, to extract energy from the beam.

It is a principal object of my invention to utilize the inherent distribution of electrons in a velocity modulated beam after passing the optimum drift distance to produce a harmonic oscillation.

Although the waves produced when the bunches are permitted to pass the optimum bunching position are rich in even harmonics, a considerable portion of the energy still is at the fundamental frequency. Unless this energy can be made to do useful work it will have to be dissipated in the form of heat or other wasteful

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forms and the circuit will consequently be of rather low efficiency.

In accordance with another feature of my invention I provide means for utilizing part of this otherwise wasted energy and so increase the efficiency of the system. One manner of accomplishing this consists in providing a resonant circuit tuned to the fundamental frequency for extracting energy from the beam after it passes the harmonic resonant circuit, and feeding back regeneratively from this latter circuit to the other tube input circuit.

A better understanding of my invention, and the objects and features thereof will be had from the particular description thereof made with reference to the accompanying drawing in which

Fig. 1 is a diagrammatic showing for the purpose of explaining my invention;

Fig. 1A shows distribution curves to explain the operation of my invention, and

Fig. 2 shows in section a preferred structural embodiment of my invention.

In Fig. 1 is diagrammatically shown a circuit arrangement for illustrating the operation of my invention. An emissive cathode 10 emits a group of electrons which are formed into a beam by accelerating electrode 11 or other means. The electrons formed in this beam are then passed through a pair of grids 13, 14, which may be arranged in an oscillating circuit 15. Oscillating circuit 15 is diagrammatically shown as a closed circuit. It is clear that any suitable tuned circuit may be used, preferably a completely closed tuned circuit is provided in order to reduce losses to a minimum. Energy for a fundamental frequency is fed into circuit 15 over a transmission line 16 and circuit 15 is tuned to this fundamental frequency. As the electron beam passes between grids 13, 14, a change in velocity is caused in certain of the electrons, the beam depending upon the instantaneous potential of the grids. The electron beam is then allowed to traverse a certain distance.

After reaching a position such as *a*, the electrons, due to the change in velocity caused by the control grids 13, 14, will become concentrated so that their distribution produces a wave form which may be illustrated as a sinusoidal wave 30, Fig. 1A. The electron beam is then allowed to traverse a further distance to tuned circuit 17.

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In traversing this additional distance the electrons in the bunched group tend to become re-distributed due to their velocity differences and further, because of interelectron repulsion. However, in the spaces between the bunches where the electrons have become more widely spaced, which is represented by the negative portion of curve 30, the change in distribution after traversing this shorter distance from A to 17 is not the same as that for the more densely bunched electrons, because of the absence of electron repulsion. Accordingly, in traversing this distance, the electron distribution is changed so as to correspond more nearly to curve 31 of Fig. 1A. It can be seen from the unsymmetrical form of this curve that the electron stream as now constituted is rich in even harmonics. Accordingly, if circuit 17 is tuned to an even harmonic, preferably the second harmonic, the bunched electrons passing between grids 20 of circuit 17 will yield energy to the tuned circuit which may be extracted by means of a line 21.

If nothing more is provided in the system the second harmonic energy may be still extracted. However, the efficiency of the system will be relatively low, since considerable energy of other frequencies still is possessed by the electron beam. Accordingly, in order to enhance the efficiency of the system, I permit the electron beam to traverse a further distance to tuned circuit 32 which is tuned to the fundamental frequency. Preferably, the spacing between 17 and 32 is such as to allow a maximum grouping of the electrons again at the fundamental frequency. The energy is then extracted from the beam by means of grids 22, 23 of tuned circuit 32, and if desired the electrons after passing through these grids may be collected on a target electrode 24 so as to remove them from the system. An output line 25 is coupled to circuit 32 and the fundamental frequency energy from 32 is fed back over a line 26 and a suitable phase adjustor 27 to input line 16. Accordingly, the energy extracted by circuit 32 serves to furnish energy in regenerative relation to the input of circuit 15. Accordingly, the efficiency of the multiplier is greatly enhanced.

It is clear that this circuit is only diagrammatically illustrated and that many various practical forms may be provided. The precise form of the resonant circuits 15, 17 and 32 is not important, since my invention will operate to produce the desired results so long as any suitable tuned circuits are provided. It is preferable, however, in order to maintain the losses of the system at a low value, to utilize low loss resonant circuits.

One practical embodiment of my invention is disclosed in Fig. 2 wherein similar reference characters are used to indicate the tube elements corresponding to those shown in Fig. 1. In this figure, cathode 10 and accelerating electrode 11 are arranged in a chamber which is closed by means of a glass seal 40. The electrons emitted by cathode 11 are guided by means of tube 41 into a resonant chamber 15 wherein they are changed in velocity by means of grids 13, 14. The electrons passing from grid 14 are then permitted to drift in a tube 42 which serves to prevent any extraneous influence on the electron beams after leaving grid 14. Electron streams then pass between grids 19, 20 and resonant chamber 17 which is tuned to an even harmonic, such as the second harmonic. A concentric line 21 is coupled to circuit 17 for extracting the harmonic energy therefrom. After leaving grid 20 the electrons

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again pass through a tube 43 to grids 22, 23, associated with a tuned resonant chamber 32 and from there the electron stream passes through a tube 44 to a sealed chamber 45 where they are collected by electrode 24. A concentric line 25 is provided for extracting energy from tuned circuit 32 and this energy is fed back over line 26 through phase shifter 27 to the input line 16 into chamber 15. Line 16 is preferably also a concentric conductor line so as to provide efficient transmission of the high frequency input energy.

It is clear that the arrangement of Fig. 2 provides a very low loss circuit, since all of the tuned circuits connected therewith are complete closed chambers which produce very little attenuation. Furthermore, by providing the concentric lines a good shielding conductor arrangement for the high frequency energy is provided.

It is clear that Fig. 2 illustrates merely a preferred embodiment of my invention and should not be considered as a limitation thereon. Many other methods of achieving the results set forth in the present application may be provided by those skilled in the art. What I consider to be my invention and desire to protect by Letters Patent is embodied in the accompanying claims.

What I claim is:

1. A frequency multiplier comprising means for producing a beam of electrons moving at a given velocity, means for modifying the velocity of electrons in said beam in accordance with a fundamental frequency, means tuned to an even harmonic of said fundamental frequency for extracting energy at said harmonic frequency from said beam of electrons so modified in velocity, means tuned to said fundamental frequency for extracting fundamental frequency from said beam, means transferring electrons leaving said means tuned to a harmonic frequency to said means tuned at fundamental frequency, and means for feeding energy from said second tuned means to said velocity modifying means.

2. A frequency multiplier comprising means for producing a beam of electrons moving at a given velocity, means for modifying the velocity of the electrons in accordance with a fundamental frequency, means tuned to an even harmonic of said fundamental frequency for extracting energy from said beam at the derived position of electron distribution of high even harmonic content, means tuned to said fundamental frequency for extracting fundamental frequency energy from said beam after passing said harmonic tuned means, and means for feeding said extracted fundamental frequency energy to said velocity modifying means in regenerative phase.

3. The method of frequency multiplication comprising forming a beam of electrons moving at a given velocity, modifying the velocity of electrons in said beam in accordance with a fundamental frequency, passing the electrons in said beam until they become bunched into a wave form rich in even harmonics by combined action of said velocity modulation and the inherent electron repulsion, extracting from said beam energy at a harmonic frequency, thereafter passing the electrons until they become bunched into a wave form rich in said fundamental frequency, extracting energy from said beam at said fundamental frequency, and feeding back said last-extracted energy further to modify the velocity of electrons in said beam.

4. A high frequency multiplier comprising means for producing a beam of electrons moving at a given velocity, means for modifying the

velocity of electrons in said beam in accordance with a fundamental frequency, means for permitting said electrons to become partially distributed in relation to the maximum bunched group in order to produce a position along said beam rich in even harmonics, means tuned to an even harmonic of said fundamental frequency for extracting energy of said harmonic frequency at the said position, followed by means tuned to said fundamental frequency for extracting fundamental frequency energy from said beam.

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