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MICROWAVE OSCILLATOR APPARATUS COMPRISING
A VELOCITY MODULATION TUBE
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Fig. 1.

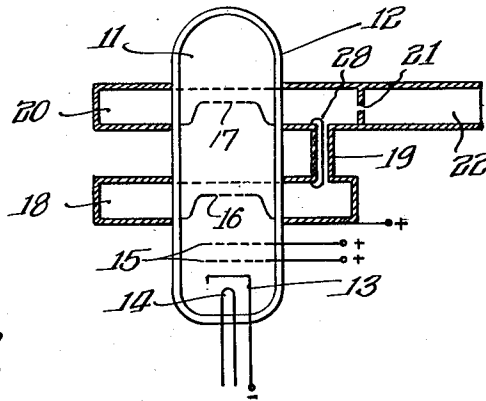


Fig. 2.

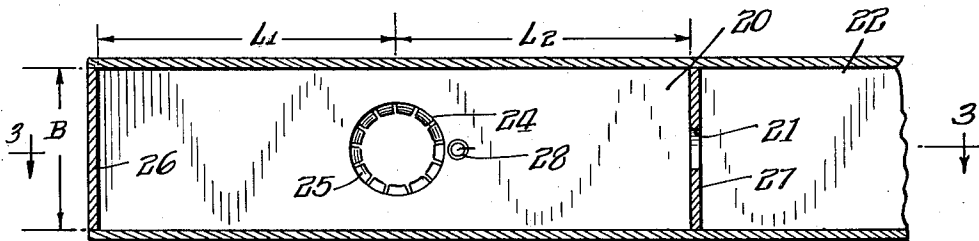


Fig. 3.

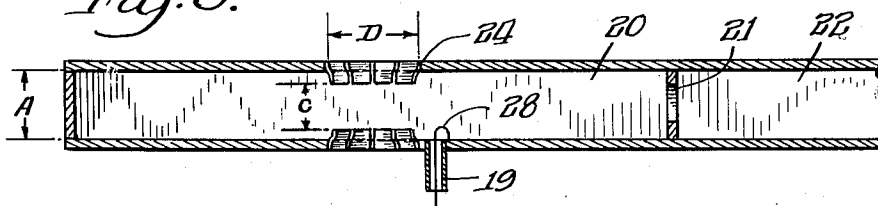
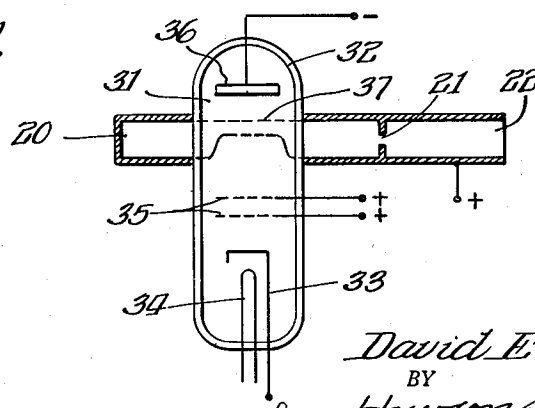


Fig. 4.



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MICROWAVE OSCILLATOR APPARATUS
COMPRISING A VELOCITY MODULATION
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4 Claims. (Cl. 315—39)

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The present invention relates to microwave generators and more particularly to oscillators utilizing velocity modulation tubes at harmonic frequencies.

At the higher frequencies in the microwave or ultra high frequency range certain factors tend to seriously limit the operation. At the higher frequencies due to the small dimensions of resonant cavities, it has heretofore been substantially impossible to employ external mechanical tuning. At the high frequencies the resonant cavity size becomes so small that the vacuum tubes employed are small in dimension thus limiting the power dissipation. In certain cases it also would be desirable to provide motor driven sweep oscillators operating at frequencies in excess of five thousand megacycles, but at those frequencies the fundamental resonant cavities have heretofore been extremely small.

In order to obviate the above mentioned disadvantages and other disadvantages encountered in the generation of microwave frequencies in the higher frequency ranges, the collector cavity of a velocity modulation tube is arranged to be resonant at two frequencies harmonically related to each other, and the cavity is so designed that the output energy can be delivered only at the higher of the two frequencies. By such an arrangement a larger cavity size is possible, larger vacuum tubes may be employed, greater power dissipation is obtainable, and other operations such as tuning are greatly facilitated. A magnetic or electric tuning probe may be used to vary the fundamental frequency and the harmonic frequency generated. By utilizing a collector cavity which is resonant to two frequencies harmonically related to each other, the conventional arrangement of a velocity modulation tube having buncher and catcher cavities may be applied, or the reflex type of tube having but a single cavity may be used.

It, therefore, is an object of the present invention to provide an improved microwave generator arranged to operate at a harmonic frequency and to deliver power only at the harmonic frequency.

It is another object of the present invention to provide a microwave generator utilizing a velocity modulation tube which has a resonant cavity resonant at two frequencies harmonically related to each other.

It is still another object of the present invention to provide an improved microwave generator operating at the higher ranges of the ultra high frequencies which is capable of supplying greater amounts of power.

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Still another object of the present invention is to provide an improved microwave generator operating at the higher frequencies which may utilize mechanical tuning means.

Other and further objects of the present invention subsequently will be described by reference to the following description taken in connection with the accompanying drawing wherein

Figure 1 is a diagrammatic representation of the application of the present invention to a velocity modulation tube utilizing two resonant cavities;

Figure 2 is a cross sectional view of one manner of constructing a cavity in accordance with the present invention;

Figure 3 is a cross sectional view of the cavity as seen in the direction of the arrows along the line 3—3 of Figure 2; and

Figure 4 shows the application of the present invention to a velocity modulation tube operating in a reflex circuit.

Referring to Figure 1 of the drawing there is shown diagrammatically a velocity modulation vacuum tube 11 having a glass envelope 12. The glass envelope 12 encloses a cathode 13 and a heater 14 therefor, focusing electrodes 15, and two sets of grids 16 and 17 extending to the exterior of the envelope for connection to suitable resonant cavities. It is apparent that the grids may be omitted, if desired, and the cavities coupled to the electron stream inductively. However, ordinarily the use of the grids is preferable. A resonant cavity 18 is connected to the first set of grids 16. The resonant cavity 18 is coupled by a coaxial line 19 to a resonant cavity 20 which is coupled through an iris 21 to a wave guide 22. Suitable potentials are supplied to the electrodes of the vacuum tube as is customary in oscillators utilizing two resonant cavities. The resonant cavity 20 is so constructed as to be resonant at two frequencies harmonically related to each other, and the iris 21 interconnecting the cavity 20 with the wave guide 22 raises the Q of the cavity at the harmonic frequency. The iris 21 serves as an impedance matching element which in some applications may be omitted. It is possible to deliver power to the wave guide 22 under such operating conditions because the bunched electrons passing between the grids 17 have a wave shape of electron density vs. time which is rich in harmonics under the proper direct current acceleration conditions.

Figures 2 and 3 show one manner of constructing the resonant cavity 20 of Figure 1. In these figures the resonant cavity 20 has a rectangular

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cross section. Opposite walls of the cavity 20 are provided with suitable apertures 24 which may be provided with suitable contact members 25 for engaging the grids 17 of the vacuum tube 11. The fundamental frequency of the cavity 20 is determined primarily by the cross sectional dimensions A and B, by the spacing C between the grids 17 and the diameter of the grids D of the cavity if the dimensions L—1 and L—2 from the center of the aperture 24 to the ends of the cavity 20 are much greater than the dimension B. The dimension B is selected so as to be small enough to prevent propagation of the fundamental mode in the wave guide. The harmonic waves at the grids may be short enough in wave length to propagate in both directions until reaching the end walls 26 and 27. The end walls 26 and 27 comprise reflectors and may be in the form of adjustable plugs. The distances L—1 and L—2 therefore are selected to bring about resonance at the desired harmonic frequency. The end wall 27 is provided with an iris opening 21 to permit some of the harmonic energy in the resonant cavity 20 to enter into the wave guide 22. A pick-up loop 28 associated with the coaxial line 19 is oriented within the cavity 20 to couple with some lines of magnetic force of the fundamental mode to produce feed back of the fundamental mode in the cavity 18 of Figure 1. The cavity 18 of Figure 1 may be of conventional design or may be constructed similarly to cavity 20.

From the representation of one manner of constructing the resonant cavity 20 it will be readily appreciated that magnetic or electric tuning devices may be used which are particularly desirable in connection with motor driven sweep oscillators operating at frequencies in excess of five thousand megacycles. Since the cavity 20 may be constructed with physical dimensions considerably larger than the dimensions obtained at the harmonic frequency, larger velocity modulation tubes may be employed to obtain greater power output. Vacuum tubes may be employed so that the fundamental frequency of the cavity 20 is in the vicinity of the upper frequency limit of the particular tube and hence large output may be obtained at the harmonic frequency because of the small power absorption, due only to cavity losses, at the fundamental frequency.

The advantages obtained by the construction heretofore described and shown as applied to the two-cavity velocity modulation tube may also be obtained with a single cavity velocity modulation tube arranged in the conventional reflex circuit. This is diagrammatically illustrated in Figure 4 wherein the velocity modulation tube 31 is of the type having a glass envelope 32 enclosing a cathode 33, a heater 34 therefor, focusing electrodes 35, a repeller electrode 36 and a pair of grids 37 adapted to be connected to a resonant cavity. The grids 37 may be connected to a resonant cavity such as the resonant cavity 20 constructed in accordance with the foregoing disclosure. The reflex circuit is one which applies the usual potentials to the vacuum tube 31 so as to obtain the necessary feed back. It will be noted that the resonant cavity 20 shown in Figure 4 is similar to that shown in Figure 1 with the exception that the cavity is not coupled to another cavity by a pick-up loop 28 and a coaxial line 19.

In a circuit of the type shown in Figure 4 a Western Electric 707-A tube was employed with

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an anode potential of four hundred volts. The repeller electrode 36 was supplied from a potential variable from zero to one hundred and fifty volts negative with respect to the cathode 33. The type of tube mentioned has only a single focusing electrode, corresponding to the focusing electrodes 35, which was connected through a one hundred thousand ohm resistor to the positive side of the anode supply of four hundred volts. The vacuum tube is mounted in the resonant cavity such as 20 having a rectangular cross section so that the dimensions A and B were $\frac{5}{8}$ inch and $1\frac{1}{4}$ inches respectively. The distances L—1 and L—2 were so adjusted as to give a strong output at a frequency of 3600 megacycles. The fundamental frequency of the resonant cavity 20 was estimated as being 2150 megacycles. It was observed that ten per cent variations in the dimensions L—1 and L—2 produced no noticeable effect in the output frequency thus illustrating that the output obtained was actually a harmonic of the fundamental oscillation frequency. It was also observed that in this particular case the reflector wall 21 could be omitted without detrimental effect as far as power output is concerned. The advantage of the present invention is clearly illustrated by the fact that a tube of this type could be made to operate to supply appreciable power at the above mentioned frequency.

While for the purpose of illustrating and describing the present invention, certain types of velocity modulation vacuum tubes have been diagrammatically indicated and others have been mentioned in the description, and one form of resonant cavity has been shown in the drawing, it is to be understood that the invention is not to be limited thereby since obviously the invention is susceptible of such other embodiments, as to tubes, cavities, and circuits as may be commensurate with the spirit and scope of the invention set forth in the appended claims.

This invention is hereby claimed as follows:

1. A microwave generator, comprising a velocity modulation tube, a rectangular cavity resonator extending transversely of said tube and adapted to receive microwave energy therefrom, the cross-sectional dimensions of said resonator providing resonance at a certain fundamental frequency, the length of said resonator also providing resonance at a harmonic of said fundamental frequency, and a wave guide coupled to one end of said resonator and having the same cross-sectional dimensions as said resonator.

2. A microwave generator, comprising a velocity modulation tube, a rectangular cavity resonator extending transversely of said tube and adapted to receive microwave energy therefrom, the cross-sectional dimensions of said resonator providing resonance at a certain fundamental frequency, the length of said resonator also providing resonance at a harmonic of said fundamental frequency, and a wave guide coupled to one end of said resonator through an iris which raises the Q of the resonator at the harmonic frequency, said wave guide having the same cross-sectional dimensions as said resonator.

3. A microwave generator, comprising a velocity modulation tube, a rectangular cavity resonator extending transversely of said tube and adapted to receive microwave energy therefrom, said resonator having inwardly extending portions for engagement with electrodes of said tube, the cross-sectional dimensions of said res-

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onator and the spacing of said portions providing resonance at a certain fundamental frequency, the length of said resonator also providing resonance at a harmonic of said fundamental frequency, and a wave guide coupled to one end of said resonator and having the same cross-sectional dimensions as said resonator.

4. A microwave generator, comprising a velocity modulation tube, a cavity resonator extending transversely of the tube and adapted to receive microwave energy therefrom, said resonator being dimensioned cross-sectionally to provide resonance at a certain fundamental frequency, and being dimensioned lengthwise to provide simultaneous resonance at a harmonic of said fundamental frequency, and means coupled to said resonator for deriving energy therefrom at said harmonic 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
2,106,768	Southworth	Feb. 1, 1938
2,129,713	Southworth	Sept. 13, 1938
2,153,728	Southworth	Apr. 11, 1939
2,372,193	Fisk	Mar. 27, 1945
2,402,184	Samuel	July 18, 1946
2,409,913	Tonks	Oct. 22, 1946
2,410,840	Samuel	Nov. 12, 1946
2,413,963	Fiske et al.	Jan. 7, 1947