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PRODUCING AND TRANSMITTING ELECTROMAGNETIC WAVES

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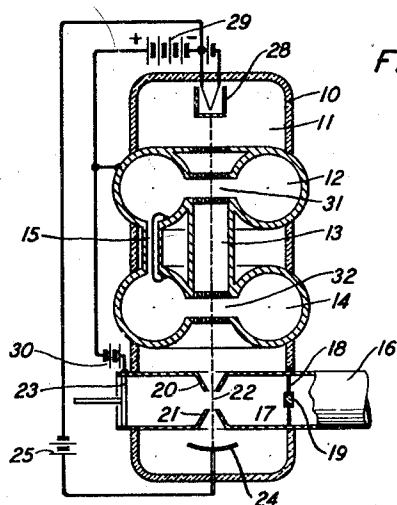


FIG. 1

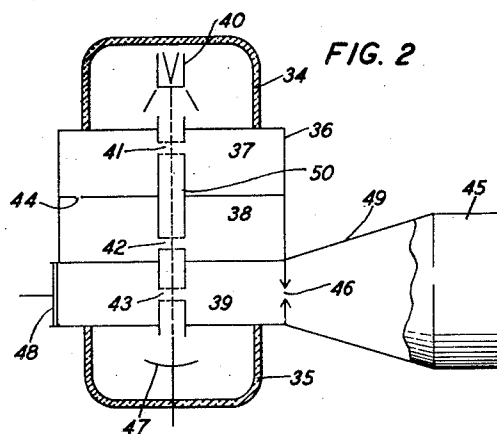


FIG. 2

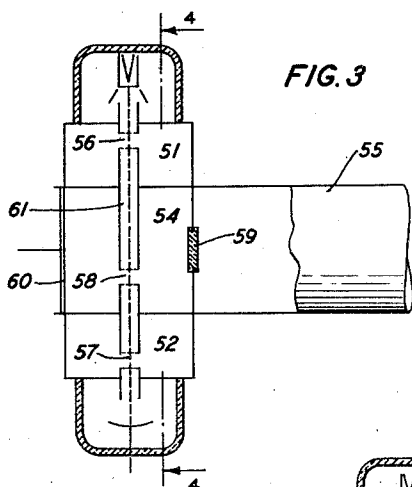


FIG. 3

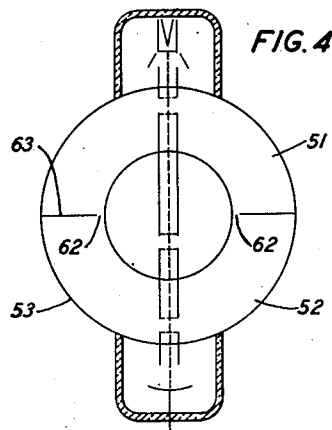


FIG. 4

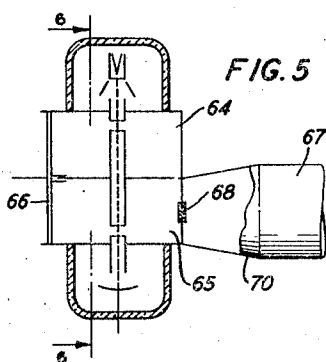


FIG. 5

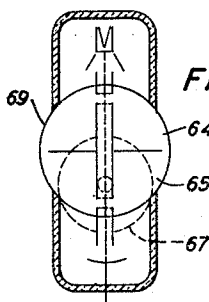


FIG. 6

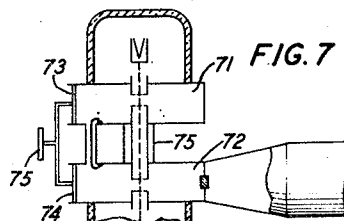


FIG. 7

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ELECTROMAGNETIC WAVESJames B. Fisk, New York, N. Y., assignor to Bell
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6 Claims. (Cl. 315—6)

This invention relates to wave transmission systems and more particularly to systems for producing and controlling very high frequency waves.

An object of the invention is to increase the compactness and efficiency of high frequency wave sources in the decimeter wave-length range.

Another object of the invention is to improve the effectiveness of the energy transfer coupling between a high frequency wave source and a wave transmission system.

A further object of the invention is to enable modulation of high frequency waves in accordance with signals or other control forces.

An additional object of the invention is to provide simple and compact apparatus for producing harmonics of very short waves.

The principles of the invention may be embodied in very divergent systems and structures. In one embodiment an electron gun is used to produce a beam which is thereafter velocity varied and caused to become "bunched" or density varied in a drift space before yielding energy to an energy-extracting field. The energy-extracting field is regeneratively coupled to the velocity varying element to cause the apparatus to produce continuous oscillations the frequency of which is determined by the resonance characteristics of closed chambers or wave guide sections which constitute the electron velocity varying and energy extraction elements. Only sufficient energy to sustain the oscillation operation is extracted from the density-varied beam and fed back to the velocity varying device. At some point between the drift space and the feedback energy extractor, or at a point beyond the extractor, additional energy is withdrawn from the density-varied beam by a resonance chamber the field of which is in such phase as to retard the beam and thus to extract energy from it. This latter chamber, which may serve to supply the load or transmission path, is accordingly wholly uncoupled to the oscillator proper except through the electron beam itself, and so presents no reaction to the oscillator. For controlling the energy supplied to the load a signal operated diaphragm or piston may vary the resonance characteristics of the two chambers of the oscillator proper or of the load coupling chamber. Variation of the former results in frequency modulation and of the latter in amplitude modulation of the wave impressed upon the wave transmission path.

Other objects and aspects of the invention will be apparent from a consideration of the following specification and appended claims taken in connection with the accompanying drawing il-

lustrating various features and embodiments of the invention.

Fig. 1 illustrates one embodiment of a density varied electron stream oscillator and load coupling in accordance with the invention;

Fig. 2 is a modification of the system of Fig. 1;

Fig. 3 is an embodiment of an alternative form of the system of Fig. 2, in which the load coupling chamber is placed intermediate the input and output chambers of the oscillator;

Fig. 4 is a partial sectional view along the line 4—4 of Fig. 3 looking in the direction of the arrows;

Fig. 5 illustrates another modification of the invention in which the load circuit is apertured coupled to the oscillator;

Fig. 6 is a partial sectional view along the plane 6—6 of Fig. 5 looking in the direction of the arrows, and

Fig. 7 illustrates a modification of the system of Fig. 5.

Referring to Fig. 1, an oscillator and load coupling system comprises an electron discharge device 10 having an electron gun 11, a resonant input chamber 12, a drift space 13 and a resonant output chamber 14 coupled in feedback relation to the input chamber 12 by a short coaxial section 15. As so far described, the structure is substantially identical with that of Fig. 5 of an article by Varian and Varian at page 325 of the Journal of Applied Physics, vol. 10, No. 5, May 1939. The electron discharge device 10 consists primarily of an envelope of glass or other insulating material united in any desired manner with the conductive structure which has been described. Passing transversely through the lower portion of the non-conducting envelope 10 is a wave guide 16. The wave guide may be rectangular or of any other desired section but is illustrated in Fig. 1 as of the conventional circular or cylindrical type. The terminal portion 17 which comprises a hollow resonance chamber 17 separated from the main structure of the guide by conducting septum 18, the central portion 19 of which is apertured to provide an electromagnetic coupling with the remainder of the guide. The portion 19 is preferably closed with an insulating closure such as glass or mica. At the central portion of the chamber 17 are inwardly directed protuberances 20 and 21, the open ends of which are separated by a short gap 22. The end of the chamber remote from the septum 18 is closed by a movable diaphragm or piston 23 which maintains the structure sealed against entrance of atmosphere but is movable under the

influence of incident sound waves to vary the resonant characteristics of the chamber. Beyond the load coupling chamber 17 and in line with the protuberances 20 and 21 is a collecting anode 24 which is externally connected electrically with the cathode 20 of the electron gun by a path including a source 25 of electromotive force. The cathode 20 of the electron gun is connected with the chamber 12 by a source 29 of focussing and accelerating electromotive force.

The chamber 17 has been shown and described as a terminal portion of a wave guide. It may, however, be instead a resonant cavity coupled to a coaxial line or other transmission system in any desired manner.

There may be connected between the chamber 14 and the chamber 17 a source 30 of potential for further accelerating the electrons. The purpose of the source 30 is to accelerate the "bunches" of electrons between gap 32 and gap 22 in order to reduce their time of flight between these two gaps. Thus little or no further "bunching" will take place and space charge forces will have little time to act in "debunching" the groups. The source of potential 25 may be such that the anode 24 is negative with respect to the chamber 17. In this event electrons will be collected at less than their maximum energy.

In operation, an electron stream projected from the electron gun passes through the gap 31 between the central perforated screens of the resonance chamber 12 and its electrons are subjected by the high frequency field at the gap to a velocity variation. In their further course through the drift space 13, decelerated electrons fall behind and accelerated electrons gain on the average velocity or non-accelerated electrons with the result that density variation occurs in the electron stream as it arrives at the gap 32 of the resonance chamber 14. With the phase of the electromagnetic field in the gap 32 such as to oppose and slightly retard the electrons, energy is extracted from the beam by the resonance chamber 14 and sufficient energy is fed back by the coaxial connector 15 to the resonance chamber 12 to maintain the operation of oscillation production. The density-varied electron stream after traversing the gap 32 is projected through the gap 22 of the load coupling chamber 17. Preferably, the gap 22 is so placed with reference to the gap 32 and the amount of energy extraction by the gap 32 is so small that the stream reaching 22 is still density varied. The resonance chamber 17 is designed to build up a strong electromagnetic field in order to extract the greatest possible amount of energy from the electron stream. The electrons retarded after passing through the gap 22 proceed to a collecting anode 24 where they are absorbed and withdrawn from the discharge device. It will, therefore, be apparent that with the resonant chambers 12 and 14 and their feedback 15 so designed as to maintain continuous oscillating action and to produce density variation of the electron stream with a minimum of energy dissipation in the chambers 12 and 14, the principal part of the energy of a high velocity stream is available for utilization at the gap 22. Moreover, the chamber 17 is effectively self-shielded from reaction in any way upon the chamber 12 or chamber 14 so that there is no electromagnetic coupling between these chambers and the resonance chamber 17 except the extremely small coupling along the electron stream itself. It is, therefore, possible to operate the system as a

whole with varying load characteristics in the wave guide 16 and even to vary the resonance characteristics of the chamber 17 to a considerable degree without any appreciable effect upon either the frequency or the intensity of the density variations of the electron beam. This is conducive to high stability as to both frequency and amplitude in the resulting oscillation energy available.

Advantage may be taken of the self-shielding feature of the load coupling to use the resonance chamber 17 for modulation purposes. Speech or other sound waves directly or indirectly impressed upon the diaphragm 23 serve to throw the chamber 17 out of resonance with its normal oscillation frequency and that of the oscillations produced thus causing the energy supplied through the aperture 19 to the wave guide system to be controlled or varied in accordance with the sound waves. The resonant chamber 17 when used for amplitude modulation in the manner which has just been described is normally tuned either above or below the frequency of the oscillations produced by an amount such that an excursion of the diaphragm 23 in one direction brings the resonance frequency of the chamber 17 toward the frequency of the oscillator while an excursion in the other direction causes the resonance frequency chamber 17 to recede from the frequency of the oscillator. The resonance characteristic of such a chamber may be made very steep and the modulating operation may cause the chamber to operate over a substantially linear portion of its resonance characteristic.

It is also possible to utilize a system of the type illustrated in Fig. 1 for the production and transmission to the wave guide 16 of oscillations which are harmonics of the natural resonance frequencies of chambers 12 and 14. For this purpose, the resonance chamber 17 may be designed to have a natural frequency which is substantially a harmonic of that of chambers 12 and 14. The operation in the production of oscillations and transfer of electromagnetic wave energy to the resonance chamber 17 will be identical with that which has been described except that the density variations or pulses of electrons reaching the gap 22 will occur at intervals of a number of cycles rather than once each cycle. Where these harmonic frequency oscillations are to be modulated, the normal tuning of the resonance chamber 17 will depart slightly from the true harmonic frequency in order to permit modulating operation on the substantially linear portion of one side of the resonance characteristic. The wave guide 16 will, of course, be designed for effective transmission of the oscillations produced in the chamber 17.

The aperture 19 is preferably made such as to enable an effective loose coupling between the resonance chamber 17 and the remainder of the wave guide 16 whereby substantially all the energy of the electromagnetic field within the resonance chamber 17 except that dissipated internally is passed on to the wave guide.

The apparatus of Fig. 2 involves an electron discharge device consisting of cup-shaped portions 34 and 35 of dielectric material sealed to a conducting structure 36 involving three resonant chambers 37, 38 and 39, preferably tuned to substantially the same frequency. An electron gun 40 within the end portion 34 projects electrons through gap 41 of chamber 37, gap 42 of chamber 38 and gap 43 of chamber 39. Between the gaps 41 and 42 is a drift tube 50 of such

length as to permit the electrons which are velocity varied at gap 41 to rearrange their relative positions so that the electron stream as a whole is density varied at the gap 42. Oscillating action is maintained by a small aperture coupling through aperture 44 between the chambers 37 and 38. Thus, a small amount of oscillating energy is fed back to the chamber 37. The density-varied electron beam traversing gap 43 yields energy to the load coupling chamber 39 which constitutes a terminal portion of the wave guide 45 and is associated therewith by an energy transfer aperture 46 sealed in the usual manner to exclude atmosphere from the electron discharge device. If desired, an adjustable conductive iris may be positioned over the outside of the aperture 46 to enable adjustment of the coupling between chamber 39 and the remainder of the wave guide 45 to the most efficient value. After extraction of a considerable portion of its energy by the chamber 39, the electron beam passes to the collecting anode 47, the external circuit of which may be the same as that of the anode 24 of Fig. 1. As in the case of Fig. 1, modulation may be effected by manipulation by sound waves or otherwise of the position of the diaphragm or piston 48 constituting an end wall of the resonant chamber 39. The chambers 37, 38 and 39 in section perpendicular to the drawing of Fig. 2 may be made circular or rectangular, as desired. The wave guide 45 may be tapered as at 49 in order to permit effective coupling to the chamber 39.

Fig. 3 illustrates another modification in which the resonant oscillator chambers 51 and 52 constitute respectively, the upper and lower hemicylindrical portions of a conductive container 53, the central portion of which receives the terminal resonance chamber 54 of a circular wave guide 55. The chambers 51 and 52 contain the modulating gap 56 and the energy-extracting gap 57, respectively. The load coupling chamber 54 contains the energy-extracting gap 58. This chamber is coupled by aperture 59 of glass or other non-conducting material to the remainder of the wave guide and the opposite end of the chamber is closed by the modulating diaphragm 60. In this structure the electron beam from the cathode gun undergoes an electron velocity varying operation at gap 56 and thereafter passes along the drift tube 61 to the gap 58. It has then become density varied and is in condition to yield a large portion of its energy to the energy-extracting chamber 54. The electrons retarded at that point pass on to the gap 57 where the chamber 52 extracts sufficient energy to feed back a sustaining force to the chamber 51 by way of the coupling aperture 62 in the conductive baffle or septum 63, shown in Fig. 4.

In Fig. 5, the resonant input chamber 64 and the resonant output chamber 65 of the oscillator are provided with a common end wall or diaphragm 66 which may be controlled in accordance with sound waves or signal or control forces to vary the resonance characteristics of the chambers 64 and 65 simultaneously. Since these resonance chambers determine the frequency of the oscillations produced and supplied to the wave guide 67 through aperture 68, it will be apparent that this device produces frequency modulation of the electromagnetic waves. In this structure the resonant output chamber of the oscillator and the resonant load coupling chamber of the wave guide are combined. It will be

understood that they may be separated in accordance with the arrangement of Fig. 2, thus permitting the load system to be effectively isolated from the oscillation-producing system from the standpoint of electromagnetic reaction of the load upon the oscillator. Where the three separate chambers are employed frequency modulation may be effected by causing the common diaphragm or end wall of all three chambers to be displaced in accordance with the modulating sound wave or other controlling force.

As indicated in Fig. 6, the chambers 64 and 65 may comprise the upper and lower hemicylindrical portions of the cylindrical container 69 and the wave guide 67 may be tapered as at 70 in order to suitably match the chamber 65 in impedance and in its effective frequency transfer characteristics.

Fig. 7 illustrates diagrammatically a modification of the structure of Fig. 5 which simplifies the mechanical construction problems involved in connection with very small resonance chambers where a considerable drift is required to provide density variation. In this structure the resonance chambers 71 and 72 between which is the drift tube 75 are provided with individual end walls or diaphragms 73 and 74 driven by a common mechanical structure 75 actuated by sound waves or other signal or control forces to vary the frequency of the oscillations produced in accordance with signals as in the structure of Fig. 5.

Although the resonance chambers and drift spaces have mostly been shown with circular symmetry about a central beam of electrons it will be understood that the beam may be broadened to pass from the electron gun to the final collector as a thin sheet of electrons. The systems of Fig. 2, 5 or 7 may readily be so modified by so designing the electron gun that its muzzle is broad in the direction perpendicular to the paper. It will be readily understood that the gaps 41, 42 and 43 and the drift tubes will likewise be broadened in that same direction as will also the anode 47. In structures of that type, the resonance chambers 37, 38, 39 and the insulating cap portions 34 and 35 will likewise be elongated in the same direction. However the resonant cavities themselves may have a variety of shapes and they do not necessarily possess complete symmetry with respect to the electron beam.

It will also be understood that all coupling apertures such as 68 of Fig. 5 may be atmospherically sealed by dielectric material and that in each of the systems illustrated energizing and other external circuits corresponding to those illustrated in Fig. 1 may be provided.

What is claimed is:

1. A system for producing and transmitting oscillations comprising an electron stream emitter, a resonant electrical device, the field of which is in the path of the electron stream to velocity vary the electrons, a second resonant electrical device, the field of which is likewise in the path of the stream at a point at which the stream is density-varied to enable the second device to extract energy from the stream, means coupling the devices to enable oscillations of the second device to be fed back to the first device, thus constituting apparatus for producing continuous oscillations, a third resonant device wholly uncoupled to the continuous oscillation-producing apparatus except that its field also intercepts the path of the electron stream at a point where density variation exists to enable it to extract energy

from the density-varied stream, means electrically biasing the third resonant device to a positive potential with respect to the second device to increase the velocities of electrons intermediate the points of the second and third resonant devices at which the electron stream is density-varied in order to reduce the transit time therebetween, and an output load transmission system to which oscillations are to be supplied electrically connected to the third resonant device whereby reaction of the output load transmission system upon the oscillation-producing apparatus is precluded.

2. In combination, a wave guide, means bounding a portion of the wave guide in such manner as to constitute a resonant electrical chamber directly coupled to the remainder of the guide, two external resonance chambers having frequency characteristics similar to that of the first, and means for impelling a stream of electrons through a portion of the fields of each of the three chambers, the separation of the positions of which the stream encounters the fields being such that velocity variation of the electrons passing through the first chamber results in substantial density variation of the stream at the points where it is exposed to the fields of the other two.

3. The combination of claim 2 in which the first two chambers are electrically coupled to permit feedback from the second to the first of energy extracted from the electron stream.

4. A cylindrical wave guide, a concentric conducting shell surrounding the guide and divided diametrically into two resonance chambers, means for projecting an electron stream through the chambers and guide to react with electric fields therein whereby velocity variation of the electrons is effected in the first chamber and energy extraction from the resulting density-modulated stream occurs in the guide and in the other chamber.

5. In combination, three resonant electrical chambers each of substantially the same natural frequency, each of said chambers having closely spaced openings, the openings of the chambers being in alignment whereby electrons may be projected through the chambers, means for projecting an electron stream through the chambers in sequence, the separation of the exit opening of the first chamber from the entrance opening of the second chamber being such that electrons velocity varied by interaction with an internal electric field of the first chamber are density varied at the position in which they enter the second chamber, whereby an internal electric field

of the second chamber may extract energy therefrom, additional coupling means between the interior of the second chamber and the interior of the first chamber feeding back energy from the second chamber to the first whereby continuous oscillations of the natural resonance of the chambers are produced, the third chamber being wholly uncoupled from the oscillation producing means except through the electron stream and having the gap between its openings positioned at a point in the stream of substantially maximum density variation, whereby an electric field within the third chamber is able to extract useful energy from the electron stream with negligible reaction upon the oscillation producing means, electrical biasing means connected between the second and third chambers to bring the third chamber to a potential considerably more positive than that of the second chamber and an output transmission system electrically connected to the interior of the third chamber to withdraw oscillation energy therefrom and otherwise uncoupled with the oscillation producing means.

6. In an electrical discharge device, an electron gun for projecting an electron stream, three substantially closed electrically conducting resonance chambers having gaps aligned with the stream to permit its passage through the electromagnetic fields of the chambers, the chambers being self-shielding to eliminate direct coupling between their fields or direct reaction upon the electron stream except in the region of their respective gaps, means whereby the first gap traversed introduces an electron velocity variation upon the stream, an external feedback to the chamber of the first-traversed gap from one of the other chambers to reinforce the electromagnetic field therein and to enhance the electron density varying operation whereby continuous oscillations ensue, an output energy utilization path connected to the remaining chamber to withdraw energy therefrom, the distances of the gaps of the other two chambers from the first gap and the velocities of the electrons being so related that the stream exhibits an effective electron density variation at their gaps whereby energy may be extracted from the stream by each of said two chambers, and means for considerably increasing the velocities of all electrons by a fixed amount intermediate the second and third gaps in order to reduce the transit time therebetween and to minimize any tendency toward decrease of the electron density variation of the stream.

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