July 1, 1947. A. E. ANDERSON 2,423,078

HARMONIC GENERATOR

Filed Oct. 20, 1943

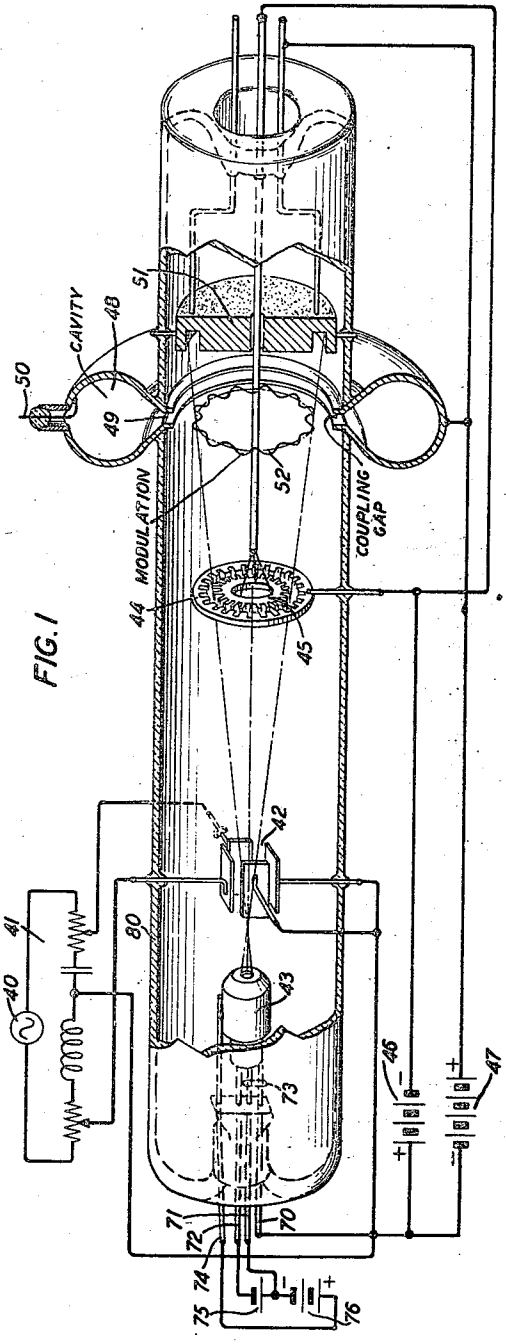


FIG. 1

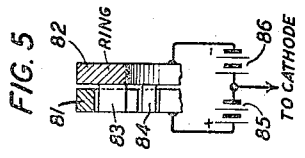


FIG. 5

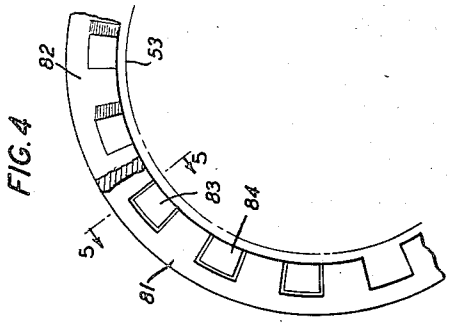


FIG. 4

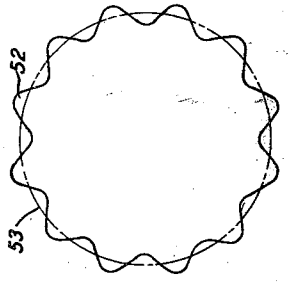


FIG. 3

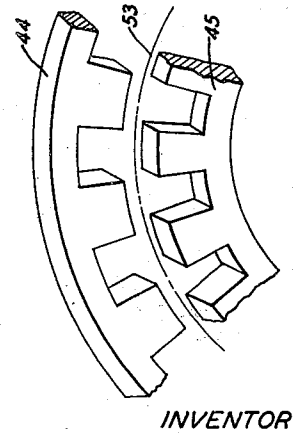


FIG. 2

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HARMONIC GENERATOR

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6 Claims. (Cl. 315—5)

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This invention relates to harmonic generators and more particularly to those involving energy interchanges between a beam of moving charged particles, for example electrons, and hollow bodies resonant to electromagnetic waves.

An object of the invention is to avoid energy losses caused by the beam striking the walls of the resonating chamber.

Another object of the invention is to abstract energy from a velocity varied stream of charged particles without the necessity of first developing electron density variations.

A feature of the invention is the use of variable deflection of an electron beam for the purpose of systematically altering the magnetic coupling between the beam considered as a current and the conductive wall of an associated internally resonant body.

A further feature is that the harmonic generation is effected by radial vibration of a rotating beam in the vicinity of an annular aperture in a toroidal resonator.

A still further feature resides in the use of electrodes, resembling in appearance a pair of toothed gears in juxtaposition, for imparting a radial vibration to a rotating electron beam.

In accordance with the invention a beam of moving charged particles is directed into the immediate vicinity of a gap in a hollow resonator, the region adjacent to the gap being characterized by a standing electromagnetic wave pattern having an electric component which varies materially from point to point. The magnitude of the magnetic coupling established between the beam considered as a current and the conductors constituting the boundary of the resonator is a function of the geometry of the system. In other words, the magnitude of the energy interchange effective between the beam and the resonator depends upon their geometric relationship or relative position. The coupling is in general varied by any relative motion between the beam and the resonator. By varying the coupling at a rate corresponding to the resonant frequency of the resonating chamber, the beam is enabled to energize the electromagnetic field in the resonator.

This application is a continuation in part of my copending application, Serial No. 421,736, filed December 5, 1941, Patent 2,409,179, issued October 15, 1946.

The invention is described in greater detail hereinafter with reference to the accompanying drawings while the scope of the invention is indicated in the appended claims.

In the drawings,

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Fig. 1 is a view of an illustrative embodiment of the invention, in perspective, partly broken away and in some respects schematic;

Fig. 2 is an enlarged fragmentary view of a component part of the system of Fig. 1;

Fig. 3 is a diagram useful in explaining the operation of systems in accordance with the invention;

Fig. 4 is an enlarged fragmentary view of a structure alternative to that shown in Fig. 2; and

Fig. 5 is a cross-sectional view of the structure shown in Fig. 4, combined with a circuit diagram.

Fig. 1 shows a harmonic generator in which a source 40, of waves the frequency of which is to be multiplied, is connected through a quarter phase network 41 to the respective pairs of deflecting plates of a conventional beam rotating arrangement 42 operating upon the electron beam from an electron gun 43 to cause the beam to sweep over a conical surface passing between two annular electrodes 44 and 45. The electrodes 44, 45 are polarized at the same potential, either positive or negative with respect to the cathode, as for example by means of a battery 46, illustrated as negative with respect to the cathode. Beyond the electrodes 44, 45 and adjacent to the path of the electron beam is mounted a toroidal resonating chamber 48 having an annular slot or aperture 49 surrounding and adjacent to the path of the rotating beam. An output coupling arrangement 50 is provided in conjunction with the resonator 48 and a collector electrode 51 is arranged for intercepting the beam after it passes the aperture 49. If desired, a battery 47 may be connected to polarize the resonating chamber 48 and the collector 51 at a positive potential with respect to the cathode.

The gun 43, the beam rotating arrangement 42, the electrodes 44 and 45 and the collector 51 are enclosed in conventional manner by a suitable envelope 80. The chamber 48 may be set into the envelope in known manner with the aperture 49 inside the envelope. Alternatively, the aperture 49 may be formed between ring electrodes sealed into the envelope and the resonant cavity may be completed by conductive members outside the envelope and conductively attached to the ring electrodes.

The gun 43 may be of any suitable type, preferably having a heating element, a cathode, and an electron accelerating electrode. Connections are indicated as being brought through the envelope 80 of the tube, a lead 70 coming from the cathode and leads 71 and 72 from the two terminals of the heating element. There is prefer-

ably an internal connector 73 connecting the cathode to one side of the heating element. A lead 74 comes from the electron accelerating element. Heating current may be supplied to the leads 71 and 72 from any suitable source, represented as a battery 75. The electron accelerating element may be polarized at a positive potential with respect to the cathode by means of a source 76 of electromotive force, such as a battery, connected as shown.

In the operation of the arrangement of Fig. 1, the electron beam sweeps out a circular conical surface except for the modifying influence of the electrodes 44, 45. These electrodes have regularly spaced projections alternately arranged, as for example in the form shown in detail in Fig. 2. The shaping of the teeth in Fig. 2 is merely illustrative of various suitable forms that may be used, the effect being to deflect the beam radially inwardly and outwardly alternately, causing the beam to describe a surface of wave-like outline as shown by the line 52 in the sectional diagram Fig. 3. There the undisturbed path of the beam is indicated by a circle 53. The effect of the electrodes 44 and 45 is to cause the beam to alternately approach and recede from the aperture 49 at a rate determined by the input frequency of the source 40 and the number of teeth in the electrode 44 or 45. The effect of the relative movement between the electron beam and the boundaries of the resonator 48 and aperture 49 is to generate in the resonator an alternating electromagnetic field. It is evident that the frequency of the field will be a multiple of the frequency of the source 40, the number of the multiple being determined by the number of teeth in either electrode 44 or 45. In other words, the input frequency is multiplied by the number of teeth in either of the two electrodes.

As the operation by means of variable coupling obtained by beam deflection is not dependent upon any electron grouping action to generate large induced electromotive forces in the output system but instead relies upon the extent and rapidity of deflection of the beam, the output with a given beam current may be effectively increased by increasing the amplitude of the impressed velocity variation. Large output currents may be generated using a large induced electromotive force in conjunction with a resonator of low effective resistance. For this purpose an internally resonant hollow conductive body is well adapted.

A construction of the radially deflecting electrodes, alternative to that of the electrodes 44 and 45 in Figs. 1 and 2, is shown in Figs. 4 and 5. Electrodes 81 and 82 are shown, of which electrode 81 may be shaped like an internal gear and may be the same as the electrode 44. The electrode 82 may be in the form of a ring with sidewise projecting teeth such as 83 and 84 interposed between and insulated from the teeth of the electrode 81. The construction differs fundamentally from that shown in Fig. 2 in that the teeth of both gears present electron deflecting surfaces on the same side of the conical surface swept out by the rotating beam. In Fig. 4 the teeth are illustrated as being outside the conical surface, the latter being represented by the circular arc 53. If desired, a similar construction may be used in which all the teeth are inside the arc 53. To effect alternate inward and outward deflection of the beam with the electrode structure shown in Figs. 4 and 5, the electrodes 81 and 82 require unequal potentials. For this purpose

polarizing sources 85 and 86, illustrated as batteries, may be connected as shown in Fig. 5, the common terminal of the sources 85 and 86 being connected preferably to the cathode.

The operation of the system of Fig. 1 with the electrodes 81 and 82 substituted for the electrodes 44 and 45 and with the polarization changed as indicated in Fig. 5 is the same as before, the electron beam being alternately attracted by the electrode 81 and repelled by the ring 82 as the beam passes the corresponding teeth.

While the shape of cross-section of the surface swept out by the modulated beam is illustrated as sinusoidal in Figs. 1 and 3 for purposes of description, the actual shape in a given case will depend upon the resulting attractions and repulsions exerted upon the beam by the particular electrode structure used. The exact shape of the curve 52 is not readily predictable, but the operation of the system will not be altered in principle whatever the shape of the curve within wide limits.

What is claimed is:

1. A harmonic generating system comprising means for forming a beam of electrically charged moving particles, beam sweeping means in the path of said beam for controlling said beam to sweep over a conical sweep path, a source of waves of fundamental frequency coupled to said beam sweeping means whereby the beam may be made to sweep over said path cyclically in synchronism with the waves from said source, a toroidal cavity resonator placed coaxially with respect to and immediately adjacent to said conical sweep path at a point beyond said beam sweeping means, said resonator having a slot immediately adjacent to said conical sweep path, whereby the oscillatory electromagnetic field of said resonator is coupled with the moving particles constituting said beam, and means to deflect the beam from said conical sweep path during a portion of each cycle of the sweep, to vary the distance between said beam and said slot, thereby enabling said beam to energize the said oscillatory electromagnetic field of said resonator, said beam deflecting means being located adjacent to the sweep path at a point intermediate between said beam sweeping means and said resonator.

2. A harmonic generating system in accordance with the preceding claim, in which the resonator surrounds the said conical sweep path.

3. A harmonic generating system in accordance with claim 1, in which the slot is annular in shape and concentric with the central axis of the resonator.

4. A harmonic generating system comprising means for forming a beam of electrically charged moving particles, beam sweeping means in the path of said beam for controlling said beam to sweep over a conical sweep path, a source of waves of fundamental frequency coupled to said beam sweeping means, whereby the beam may be made to sweep over said path cyclically in synchronism with waves from said source, a toroidal cavity resonator placed coaxially with respect to and immediately adjacent to said conical sweep path at a point beyond said beam sweeping means, said resonator having a slot immediately adjacent to said conical sweep path, whereby the oscillatory electromagnetic field of said resonator is coupled with the moving particles constituting said beam, and stationary electrostatic means at a point in the path of the beam between said beam sweeping means and said resonator to deflect the beam periodically from its

initial path to vary the distance between said beam and said slot with a periodicity equal to the resonant frequency of the toroidal cavity resonator.

5. A harmonic generating system comprising a source of waves, the frequency of which is to be multiplied, means for producing and maintaining a beam of moving electrically charged particles, means coupled to said source of waves to rotate said beam, whereby said beam is enabled to trace out an initially substantially conical surface once per cycle of said waves, a pair of annular electrodes placed one outside and the other inside said conical surface in proximity to the path of said rotary beam, said electrodes having regularly spaced projections of equal number on each electrode, a projection of one electrode being opposite an indentation in the other electrode, means connected to said electrodes to maintain a substantially constant potential upon said electrodes to periodically deflect said beam alternately inwardly and outwardly from said initial surface, and a hollow toroidal conductor internally resonant to a multiple of the frequency of said wave source, said conductor being mounted beyond said annular electrodes and concentrically with said conical surface and having an annular aperture in proximity to the path of said rotary beam, the ratio between the resonant frequency of said conductor and the frequency of said wave source being determined by the number of projections in either of said annular electrodes.

6. A harmonic generating system comprising a source of waves, the frequency of which is to be multiplied, means for producing and maintaining a beam of electrically charged particles, means coupled to said source of waves to rotate said beam, whereby said beam is enabled to trace out an initially substantially conical surface once per cycle of said waves, a pair of annular electrodes placed on one and the same side of said conical surface in proximity to the path of said rotary beam, said electrodes having regularly spaced projections of equal number on each electrode, a projection of one electrode being inserted between two adjacent projections on the other electrode and insulated therefrom, means connected to said electrodes to maintain a substantially constant potential difference between said electrodes to periodically deflect said beam alternately inwardly and outwardly from said initial surface, and a hollow toroidal conductor internally resonant to a multiple of the frequency of said wave source, said conductor being mounted beyond said annular electrodes and concentrically with said conical surface and having an annular aperture in proximity to the path of said rotary beam, the ratio between the resonant frequency of said conductor and the frequency of said wave source being determined by the number of projections on either of said annular electrodes.

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