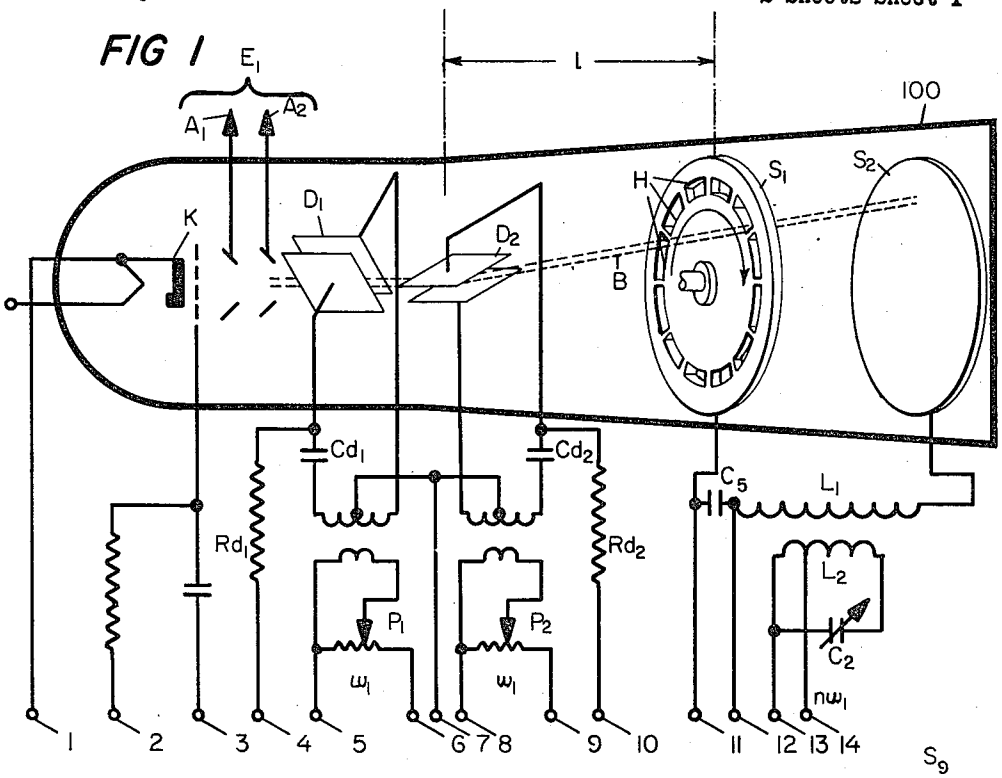
March 7, 1961 O. E. H. RYDBECK ET AL 2,974,295

FREQUENCY ADDITION AND SUBTRACTION BY MEANS OF AUXILIARY DEFLECTION ELECTRODES IN A CATHODE RAY TUBE

Filed April 29, 1957 2 Sheets-Sheet 1

FIG 1



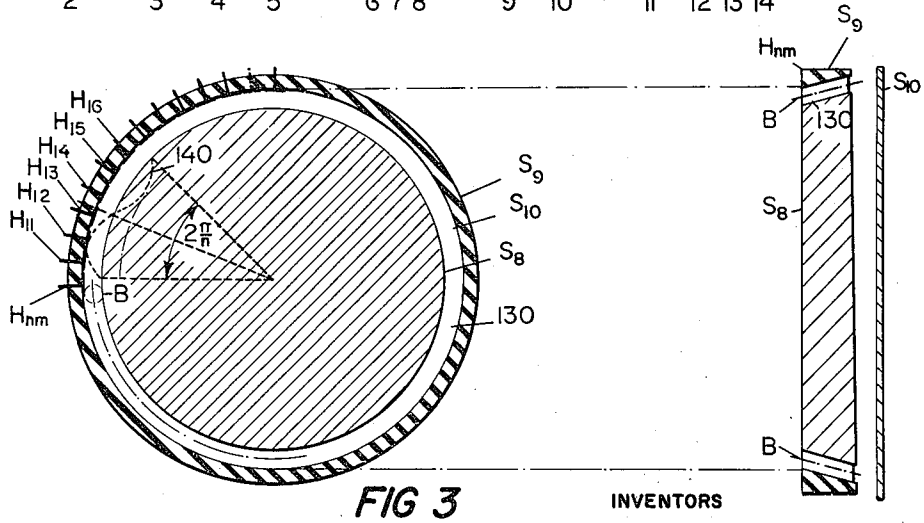


FIG 3

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2 Sheets-Sheet 2

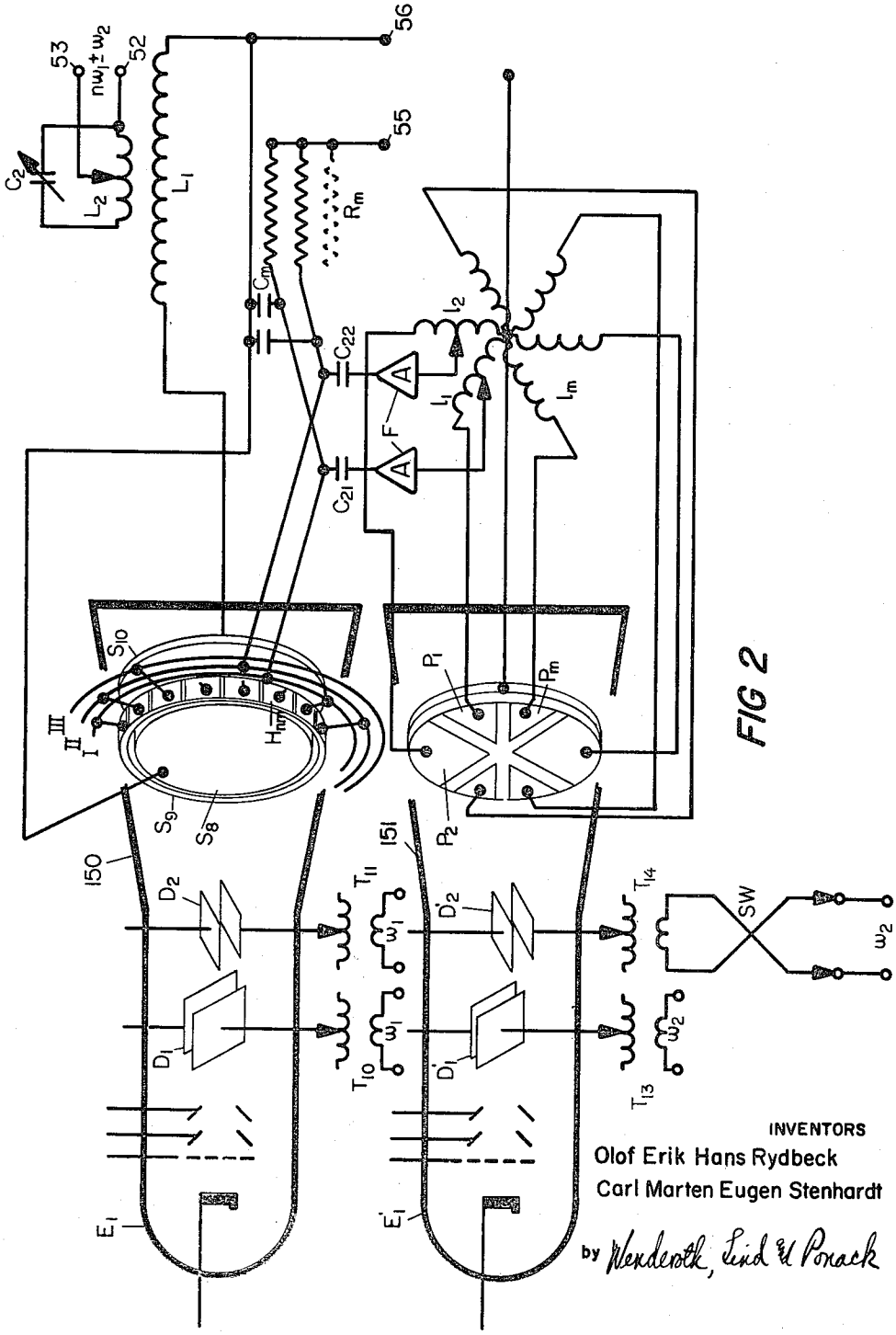


FIG 2

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FREQUENCY ADDITION AND SUBTRACTION BY MEANS OF AUXILIARY DEFLECTION ELECTRODES IN A CATHODE RAY TUBE

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5 Claims. (Cl. 332—58)

This invention relates to an electronic apparatus utilizing a cathode ray, the main purpose of which is to obtain frequency addition and frequency subtraction and frequency multiplication of electrical signals.

It has been proposed to obtain frequency multiplication by means of a cathode ray tube, the electron beam of which is deflected so as to describe a circular track on a target electrode. In front of said target electrode another electrode is disposed, said last mentioned electrode being provided with a number of apertures regularly displaced along the path that is swept by the electron beam. If the angular sweep frequency of the electron beam is ω_1 and the number of regularly spaced apertures is n, an alternating voltage of the angular frequency $n \cdot \omega_1$ will appear between the target electrode and the apertured electrode.

According to this invention the general operating principle of this known arrangement can be utilized for obtaining further effects such as frequency addition, frequency subtraction or frequency modulation.

Other objects of the invention will appear from the following description, with references to the accompanying drawings, in which:

Fig. 1 illustrates a frequency multiplying electronic arrangement of a known construction,

Fig. 2 shows a device according to the invention by means of which frequency addition or frequency subtraction together with frequency multiplication can be obtained, and

Fig. 3 illustrates a detail of the arrangement of Fig. 2 on a greater scale.

In Fig. 1 E_1 designates an electron gun with a cathode K, a control grid G, accelerating electrodes A_1 and A_2, two pairs of deflection electrodes D_1 and D_2, an apertured plate S_1, and a target electrode S_2. The system comprising these elements is enclosed in a glass tube **100**. It is assumed that the two pairs of deflection plates are supplied with voltages of the same frequency but with a phase difference of 90°. The electron beam B thereby is deflected so as to make a circular sweep in the one or the other direction. By means of potentiometers P_1 and P_2 connected to the input terminals **5**, **6** and **8**, **9**, respectively, for the deflection voltage this voltage can be suitably adjusted. Two capacitors Cd_1 and Cd_2 are used for enabling a D.C. voltage to be supplied to one deflection plate in each pair, for the purpose of adjusting the location of the center point of the circular sweep.

The plate S_1 is provided with apertures H and is so located in the tube that the electron beam during its sweep passes said apertures one after another, said apertures being regularly spaced and located at the same distance from the center of the plate S_1. When the beam passes one of the apertures H and strikes the collector electrode S_2 a current pulse will pass from the plate S_1 to the collector electrode S_2.

If the angular frequency of the deflection voltage is ω_1 and the number of apertures in the plate S_1 is n an

A.C. voltage with an angular frequency equal to $n \cdot \omega_1$ will appear between the plates S_1 and S_2.

Between the plates S_1 and S_2 a tank circuit is connected comprising a transformer T_3 with a primary winding L_1 and a secondary winding L_2, the latter being tuned by means of a capacitor C_2. In series with the primary winding L_1 a capacitor CS is connected which is intended to be a blocking condenser.

If it is assumed that the apertured plate S_1 in the arrangement according to Fig. 1 is rotatable and if the angular frequency of rotation is equal to the angular sweep frequency of the electron beam and rotation is taking place in the same direction as the sweep, the frequency obtained from the collector plate will be zero.

If the apertured plate is rotating in the opposite direction but with the same angular frequency as the angular sweep frequency ω_1 a voltage with an angular frequency of $2n \cdot \omega_1$ will appear between the plates S_1 and S_2.

If the angular frequency of rotation of the plate S_1 is ω_2 the angular frequency of the voltage between S_1 and S_2 will be $n(\omega_1 - \omega_2)$ if the direction of the rotation is the same as the direction of the sweep and $n(\omega_1 + \omega_2)$ if the relative directions of rotation are opposite.

The rotatable plate S_1 can be considered as a suppressing means with n suppressing and n non-suppressing parts, regularly distributed along the sweep path of the electron beam, said suppressing means being movable with a periodicity with the angular frequency ω_2.

It may be advantageous to avoid mechanically movable parts within an evacuated tube, and, therefore, the rotatable plate S_1 can be replaced by a rotating deflection field, serving as a suppressing means as described.

Fig. 2 illustrates an embodiment of the invention in which means are provided for producing such a deflection field. Instead of the plates S_1, S_2 in the device according to Fig. 1 an electrode system is employed, comprising a central circular plate or the like, S_8, an annular member S_9 arranged concentrically about said plate, and a collector electrode S_{10} arranged behind S_8 and S_9. Between S_8 and S_9 there is an annular gap with a certain, suitable depth in the direction of the electron beam, through which gap the electron beam can pass when it is performing a circular sweep. The annular member S_9 comprises a plurality of electrode plates H_{nm} insulated from each other and arranged side by side. When the beam is passing through the gap **130** during its circular sweep it will be influenced by any existing voltage between the plates H_{nm} and the plate S_8, whereby it will be deflected towards the plate S_8 or towards the plates H_{nm}. A voltage of the order of, say 6 volts between the plate S_8 and the plates H_{nm} may be required for a complete deflection of the electron beam so that it will not strike the plate S_8. In case no such voltage exists the electron beam will pass through the gap without being disturbed by any influence. In the case just mentioned, where a complete deviation is obtained with a voltage of 6 volts, it can be assumed that about half that deviation will be obtained with a voltage of 3 volts whereby one half of the electron beam will impinge upon either of the plates S_8 or the plates H_{nm}, while the other half will pass through the gap **130**. If, therefore a bias of 3 volts D.C. is superposed on an alternating voltage of 3 volts the electron beam will oscillate in a radial direction. At maximum phase of the alternating voltage the beam will strike the plate S_8 and at minimum phase it will pass freely through the gap **130** without striking any of the plates. Though a plurality of other possibilities of control are possible, only those cases will now be considered in which the electron beam at maximum phase of the said voltage is totally deflected from the gap **130** and at minimum phase freely passes said gap, whereby the

effects obtained with the arrangement according to Figs. 2 and 3 will be studied.

The electrodes H_{nm} are connected in a multiphase circuit as shown in Fig. 2 whereby adjacent plates are connected to different phases of a multiphase system which in Fig. 2 is shown as a 6-phase system although any other number of phases can be used. The passing of the electron beam through the annular gap **130** will now vary depending on the multiphase voltage, for example in a manner such as is illustrated by the curve **140** in Fig. 3. At a certain moment on the plate H_{12} the deflection of the beam in an outward direction is maximum and in this case it is assumed that the beam passes freely through the annular gap **130** and strikes the plate S_{10}, while simultaneously at the plate H_{15} the deflection inwardly is maximum, whereby the electron beam entirely strikes the plate S_8.

According to Fig. 2 the electrode arrangement is inserted in a tube **150** which tube further comprises an electron gun E_1 and deflection plates D_1 and D_2. The deflection plates are connected to transformers T_{10}, T_{11} each of which is connected to a source of alternating voltage with an angular frequency ω_1, for imparting a circular sweep to the electron beam. The plates H_{nm} of the annular member S_9 are connected in a 6-phase circuit, of which the phases I, II and III are shown in the figure. The collector plate S_{10} is connected to a tank circuit comprising coils L_1 and L_2 and an adjustable condenser C_2. The coil L_2 is connected to terminals **52** and **53**, which are the output terminals of the circuit.

The multiphase voltage generator circuit comprises an axiliary cathode ray tube **151**, the target electrode of which is divided in a number of sectors P_1, P_2–P_m, corresponding to the number of phases. Further, this tube comprises an electron gun E_1 and two pairs of deflection plates D_1' and D_2' for imparting a circular deflection to the electron beam. The sectors P_1–P_m are connected to coils l_1–l_m respectively, in a multiphase circuit.

The deflection plates D_1' and D_2' are adjustably connected to the secondary sides of transformers T_{13}, T_{14}, the primary sides of which are connected to sources for deflection voltages of a frequency ω_2, for producing a circular sweep, whereby a pole changer SW is connected to the primary winding of the transformer T_{14}. In operation, when the electron beam sweeps over the sectors P_1 to P_m of the tube **151** a 6-phase voltage will be supplied to the coils l_1–l_m.

From connecting contacts of the coils l_1–l_m connections are made to corresponding phases of the multiphase circuit in which the plates H_{nm} are included, said connections being made via condensers C_{21}, C_{22} etc. via suitable amplifiers F, as the voltage that can be obtained from the coils l_1–l_m will be too low to deflect the electron beam in the tube **150**.

A D.C. bias voltage is applied to the plates H_{nm} via terminals **55**, **56** and resistors R_m. By changing the phase 180° by means of the switch SW connected to the plates D_2' it is possible to reverse the direction of rotation of the sweep of the electron beam. The field of the 6-phase system will then rotate in an opposite direction than before the reversal.

The multiphase field between the plates H_{nm} and the electrode S_8 in Fig. 2 is rotating with a rapidity of Rf revolutions per second, whereby

$$Rf=\frac{\omega_2}{2\pi_n}$$

where ω_2 is the angular frequency of the deflection voltage applied to the deflection plates D_1' and D_2' of the tube **151**, and n is the number of poles of the multiphase system constituted by the plate H_{nm}.

The electron beam in the tube **150** will rotate with a rapidity of Rb revolutions per second, Rb being determined by the equation:

$$Rb=\frac{\omega_1}{2\pi}$$

where ω_1 is the angular frequency of the deflection voltage applied to the deflection plates D_1 and D_2 of the tube **150**.

If it is assumed that $Rf=Rb$, i.e.

$$\frac{\omega_2}{n}=\omega_1$$

and that the direction of rotation of the beam and the multiphase field is the same, a substantially constant output voltage from the plate S_{10} in the tube **150** will be obtained, the magnitude of said output voltage being dependent on the bias voltage applied to the terminals **55** and **56**. If, on the other hand,

$$\frac{\omega_2}{n}$$

differs from ω_1 an output voltage is obtained with an angular frequency that is proportional to

$$\omega_1+\frac{\omega_2}{n}$$

if the alternating field produced by the plates H_{mn} has a direction of rotation that is opposite to the rotational direction of the sweep in the tube **150**, and proportional to

$$\omega_1-\frac{\omega_2}{n}$$

if the alternating field is rotating in the same direction as the sweep in the tube **150**.

The original intention with the arrangement according to Figs. 2 and 3 was to enable a displacement of a carrier wave to be made upwards or downwards in respect of its frequency. In this case $n\cdot\omega_1$ is meant to be the fundamental angular frequency of the carrier wave while ω_2 is meant to be the figure by which it is desired to displace that carrier wave in one or the other direction. With the arrangement according to Fig. 2 it will be possible to achieve such displacement simply by operating the switch SW, said displacement being from the angular frequency

$$n\left(\omega_1+\frac{\omega_2}{n}\right) \text{ to } n\left(\omega_1-\frac{\omega_2}{n}\right)$$

and vice versa.

It is evident that by means of the circuit according to Fig. 2 it is possible to obtain frequency multiplication as well as frequency addition and frequency subtraction. If a 6-phase system is chosen and it is desired to multiply by 12, there must be $12\times6=72$ plates H_{mn}.

With such a tube it is of course possible to connect the electrodes H_{nm} together in some other way than has been assumed above. If for example, the plates are connected together two and two, a frequency multiplication with the factor 6 instead of 12 will be achieved. If the plates are connected together four and four a frequency multiplication with the factor 3 will be obtained. Further, it may be observed that if a four phase system instead of a 6 phase system is used, it is possible to connect the 72 plates in such way that 18 plates per phase are obtained, which gives a frequency multiplication with the factor 18. In this case, however, the output frequency will be less free from unwanted frequencies.

It should be observed in this connection that a multiphase voltage generator, involving the tube **151** according to Fig. 2, may be used as a separate unit for supplying a multiphase voltage to some other apparatus or for some other purpose than the multiphase frequency changer shown in Fig. 2.

As will be evident to anyone skilled in the art a great number of other modifications of the invention can be made without departing from the main principle of the same.

We claim:

1. An electronic apparatus for obtaining frequency addition or frequency subtraction of two frequencies f_1 and f_2, said apparatus comprising a tube, an electron gun for generating an electron beam within said tube, first deflecting means in said tube for imparting a periodic deflection of said beam in a predetermined, periodical sweep along a closed sweep path with a frequency of f_1 cycles per second, a target electrode in said tube, a plurality of auxiliary deflecting means located near said target electrode between said first deflection means and said target electrode, said auxiliary deflection means being symmetrically disposed along said closed sweep path and being divided into m groups each having n auxiliary deflection means therein, where m is an integer greater than 1 but less than the number of auxiliary deflection means, the deflection means of each of the groups of such deflection means being interspersed among the auxiliary deflection means of the other groups, a source of multiphase energy having a frequency f_2 and m phases, connecting means connecting each phase of said source to a different one of said groups of deflection means for producing an auxiliary deflection field having m phases and n pole pairs, said auxiliary deflection field moving along said deflection path at a frequency of f_2/n cycles per second, said auxiliary deflection field causing a periodical auxiliary deflection of said beam to and from said target electrode during its sweep along said closed path, and a tank circuit tunable to the frequencies $n \cdot f_1 + f_2$ or $n \cdot f_1 - f_2$ for deriving an alternating output energy from said target electrode of the frequency of $n \cdot f_1 \pm f_2$ cycles per second.

2. An electronic apparatus for obtaining frequency addition or frequency subtraction of two frequencies f_1 and f_2, said apparatus comprising a tube, an electron gun for generating an electron beam within said tube, first deflecting means in said tube for imparting a periodic deflection of said beam in a predetermined, periodical sweep along a closed sweep path with a frequency of f_1 cycles per second, a target electrode in said tube, a plurality of auxiliary deflecting means located near said target electrode between said first deflection means and said target electrode, said auxiliary deflection means being symmetrically disposed along said closed sweep path and being divided into m groups each having n auxiliary deflection means therein, where m is an integer greater than 1 but less than the number of auxiliary deflection means, the deflection means of each of the groups of such deflection means being interspersed among the auxiliary deflection means of the other groups, a source of multiphase energy having a frequency f_2 and m phases, connecting means connecting each phase of said source to a different one of said groups of deflection means for producing an auxiliary deflection field having m phases and n pole pairs, said auxiliary deflection field moving along said deflection path at a frequency of f_2/n cycles per second, said auxiliary deflection field causing a periodical auxiliary deflection of said beam to and from said target electrode during its sweep along said closed path, and a tank circuit tunable to the frequencies $n \cdot f_1 + f_2$ or $n \cdot f_1 - f_2$ for deriving an alternating output energy from said target electrode of the frequency of $n \cdot f_1 \pm f_2$ cycles per second, and means for reversing the relative direction of movement of the beam and the auxiliary deflection field along said sweep path.

3. An electronic apparatus for obtaining frequency addition and frequency subtraction, said apparatus comprising a tube, an electron gun for generating an electron beam in said tube, first deflection means in said tube for imparting a periodic deflection of said beam along a predetermined circular sweep path, said first deflection means comprising two pairs of deflection members arranged to deflect said beam in directions at an angle of 90° to each other, a two phase alternating energy supply source, each of said deflection means being connected to a different one of the phases of said two phase alternating energy supply source, said source having a frequency of f_1 cycles per second, a target electrode in said tube located in said sweep path, a plurality of auxiliary deflecting members symmetrically arranged around said sweep path between said first deflecting means and said target electrode, said deflection members being divided into m groups each having n auxiliary deflection means therein, where m is an integer greater than 1 but less than the number of auxiliary deflecting members, the deflecting members of each of said groups being symmetrically disposed along said sweep path and the deflecting members of each group being interspersed among the auxiliary deflecting members of the other groups, a source of multiphase energy having m phases and a frequency of f_2 cycles per second, connecting means connecting each phase of said source of multiphase energy to all deflecting members of one of said groups of deflecting members for producing a rotating auxiliary deflection field within said tube, said auxiliary deflection field having m phases and n pole pairs, said auxiliary deflection field rotating around a path which is concentric to said circular deflection path, the speed of rotating of said auxiliary deflecting field being f_2/n revolutions per second, said auxiliary deflection field causing a periodical auxiliary deflection of said beam to and from said target electrode during its sweep along said path, and a tank circuit tunable to the frequencies $n \cdot f_1 + f_2$ or $n \cdot f_1 - f_2$ for deriving an alternating output energy from said target electrode of the frequency of $n \cdot f_1 \pm f_2$.

4. An electronic apparatus for obtaining frequency addition and frequency subtraction, said apparatus comprising a tube, an electron gun for generating an electron beam in said tube, first deflection means in said tube for imparting a periodic deflection of said beam along a predetermined circular sweep path, said first deflection means comprising two pairs of deflection members arranged to deflect said beam in directions at an angle of 90° to each other, a two phase alternating energy supply source, each of said deflection means being connected to a different one of the phases of said two phase alternating energy supply source, said source having a frequency of f_1 cycles per second, a target electrode in said tube located in said sweep path, a plurality of auxiliary deflecting members symmetrically arranged around said sweep path between said first deflecting means and said target electrode, said deflection members being divided into m groups each having n auxiliary deflection means therein, where m is an integer greater than 1 but less than the number of auxiliary deflecting members, the deflecting members of each of said groups being symmetrically disposed along said sweep path and the deflecting members of each group being interspersed among the auxiliary deflecting members of the other groups, a source of multiphase energy having m phases and a frequency of f_2 cycles per second, connecting means connecting each phase of said source of multiphase energy to all deflecting members of one of said groups of deflecting members for producing a rotating auxiliary deflection field within said tube, said auxiliary deflection field having m phases and n pole pairs, said auxiliary deflection field rotating around a path which is concentric to said circular deflection path, the speed of rotating of said auxiliary deflecting field being f_2/n revolutions per second, said auxiliary deflection field causing a periodical auxiliary deflection of said beam to and from said target electrode during its sweep along said path, and a tank circuit tunable to the frequencies $n \cdot f_1 + f_2$ or $n \cdot f_1 - f_2$ for deriving an alternating output energy from said target electrode of the frequency of $n \cdot f_1 \pm f_2$, and means for reversing the relative direction of rotational

movement of said beam along said sweep path and said rotating auxiliary deflection field.

5. An electronic apparatus for adding or subtracting a first and a second frequency, said apparatus comprising a tube, an electron gun in said tube for generating an electron beam, means for deflecting said electron beam along a circular sweep path with a periodicity corresponding to said first frequency, a target electrode in said tube, means for generating a rotatable, multipole, multiphase deflection field within said tube between said electron gun and said target electrode with a rotational axis coinciding with the axis of said circular sweep path for deflecting said electron beam to and from said target electrode during its sweep along said sweep path, means for rotating said multiphase deflection field with a rotational speed corresponding to said second frequency divided with the number of pole pairs of said multipole, multiphase deflection field, means for deriving from said target electrode an output energy of a frequency which is the sum or the difference of said first frequency multiplied with the number of pole pairs of said multipole, multiphase deflection field and said second frequency, and means for reversing the relative direction of rotation of said beam along said sweep path and said multiphase, multipole deflecting field.

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