Oct. 18, 1932. W. A. MARRISON 1,882,850

FREQUENCY PRODUCER

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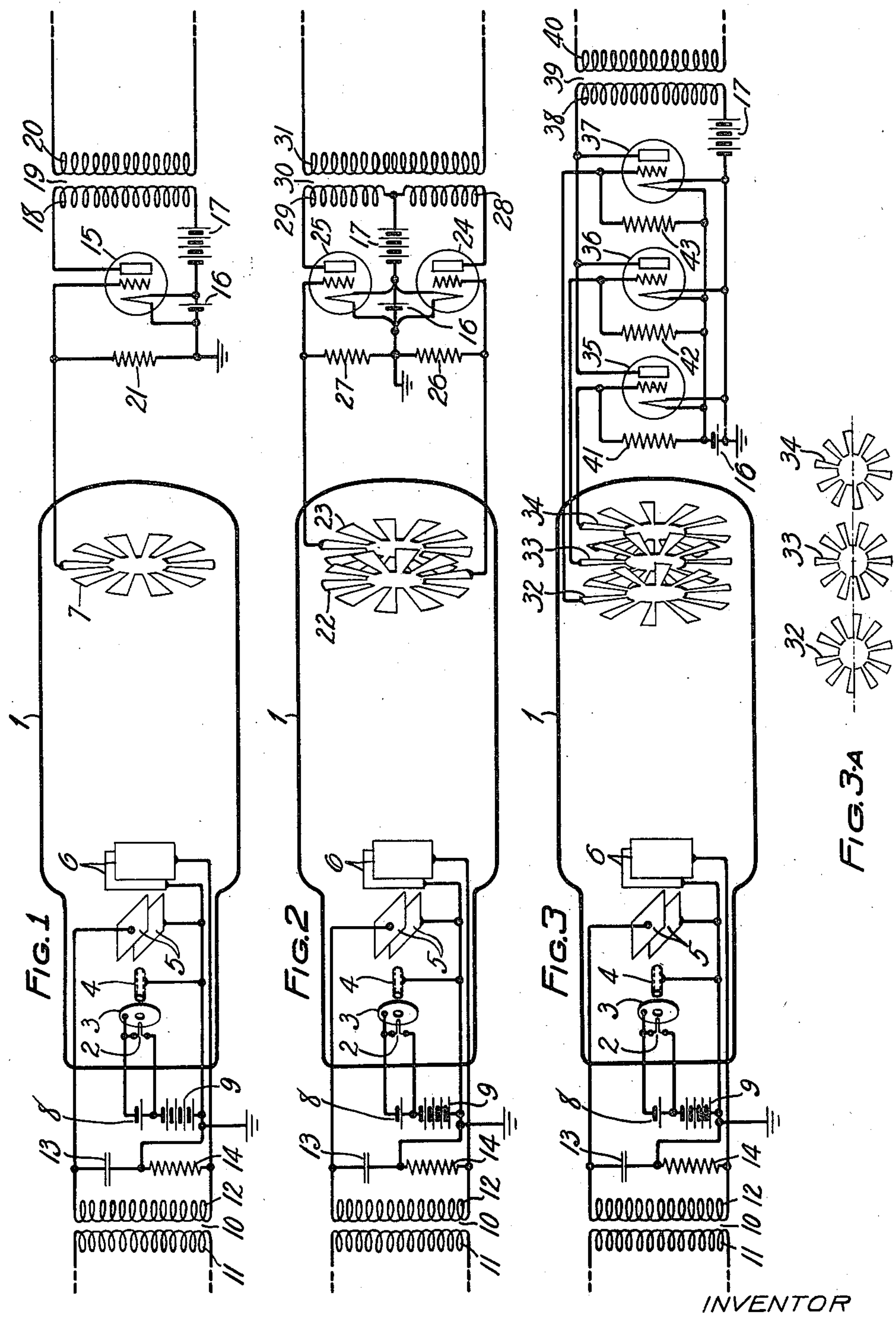

FIG. 1

FIG. 2

FIG. 3

FIG. 3A

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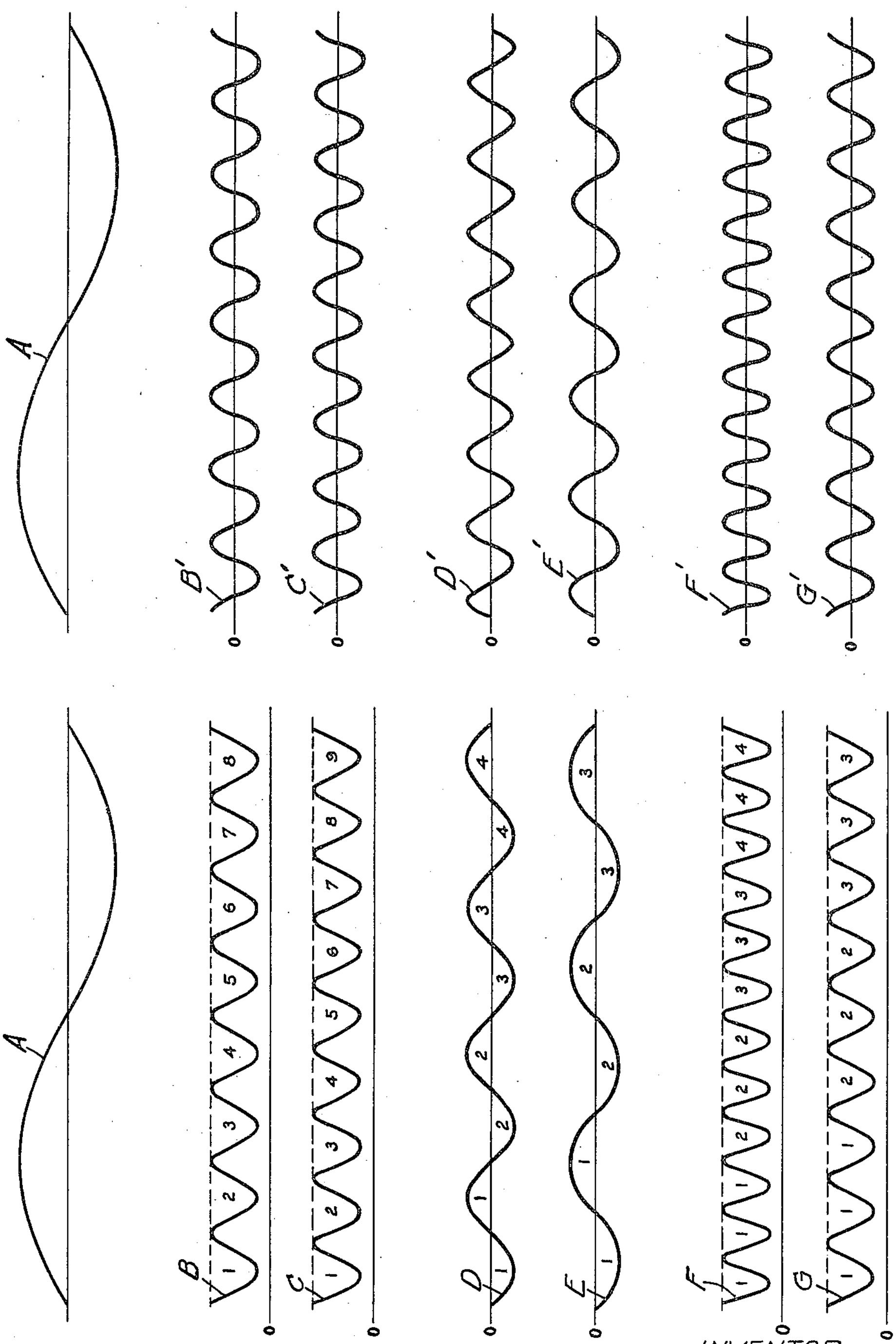
FIG. 4

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# UNITED STATES PATENT OFFICE

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## FREQUENCY PRODUCER

Application filed August 5, 1929. Serial No. 383,622.

This invention relates to harmonic frequency production, and especially to the production of electrical variations the frequency of which has a predetermined integral relation to the frequency of given electrical variations from which the harmonic frequency variations are derived.

Objects of the invention are: to generate waves whose freqeuncy has a given integral relation to a given wave in a more simple and positive manner, and with greater stability, than as in accordance with prior inventions, with greater economy of operation and of plant, with substantial independence from variation of characteristics of the wave used in the production, and with avoidance of the production of extraneous waves such as frequently attends harmonic wave productions by prior methods or means.

A typical form of the invention utilizes a cathode ray tube of somewhat the same form as used, for example, in cathode ray oscillographs. The cathode ray is caused, by a wave of the fundamental frequency, to trace and cyclically retrace at the fundamental frequency a predetermined fixed path or figure. The desired harmonic frequency is a function of the frequency of incidence of such wave on a target interposed in its path. If, for example, the target has the form of a spoked wheel the frequency of incidence of the ray on such a target, and therefore the frequency of variation of the electrical charge on the target from the impinging electrons, is a function of the number of spokes. The variation in charge is translated into a correspondingly varying current by, for example, a thermionic repeating device the control element of which is connected to the target.

The invention will be more readily understood from the following detailed description taken in connection with the accompanying drawings, in which:

Fig. 1 represents one embodiment employing a cathode ray tube equipped with deflector plates and a single target connected to a space discharge amplifier;

Fig. 2 represents another embodiment employing a cathode ray tube equipped with two parallel targets associated with a push-pull amplifier having differentially-connected output circuits;

Fig. 3 represents still another embodiment employing a cathode ray tube equipped with a plurality of parallel targets associated with thermionic amplifying devices having cumulatively connected output circuits;

Fig. 3A is a developed view of the three targets employed in the device of Fig. 3;

Fig. 4 is a set of curves showing various harmonic frequencies that may be produced from the fundamental wave supplied to the deflector plates in systems similar to those shown in Figs. 1 to 3.

Referring to Fig. 1, the reference numeral 1 designates a cathode ray tube similar to that shown in U. S. Patent 1,603,284, granted to J. B. Johnson October 19, 1926, except that the fluorescent screen is omitted. The tube is equipped with a cathode 2, a screening electrode 3, an anode 4, two pairs of deflecting plates 5 and 6, and a target 7 which has a plurality of projections or spokes. The target has an odd or even number of spokes depending on whether odd or even harmonics of the frequency supplied to the deflector plates are desired. It should be observed that the width of each spoke varies directly as the distance from the center and that at any given radius, the distance between adjacent spokes equals the width of the spokes.

Heating current for cathode 2 is supplied from battery 8 and positive potential for the anode 4 is supplied from battery 9. The transformer 10, including primary winding 11 and secondary winding 12, serves as a means of transferring energy of the fundamental frequency to the cathode ray tube deflector plates. Condenser 13 and resistance 14 together with the secondary winding 12 of transformer 10 form a phase-splitter similar to that described in my copending application No. 252,628, filed February 7, 1928, Patent No. 1,768,262, granted June 24, 1930.

The reference numeral 15 designates a space discharge tube having the usual cathode, anode and control electrode, the last mentioned element being connected to target 7. The cathode is heated by energy supplied from battery 16. Energy for the anode circuit is supplied from battery 17, which has its positive terminal connected to the anode through the primary winding 18 of transformer 19. The secondary winding 20 of transformer 19 may be connected to another amplifier or to a work circuit. The high resistance grid leak 21 permits the electrons to flow from the control electrode to the cathode at such a rate as will prevent the control electrode from becoming excessively negative and blocking the tube.

In operation, electrons emanate from the heated cathode 2 and are drawn through the orifice in the screening electrode 3 to the tubular anode 4. The velocity of the electrons is such that some of them pass through the tubular anode and impinge upon target 7. At the same time energy of a fundamental frequency is supplied through transformer 10 to the two pairs of deflector plates 5 and 6. The potential applied to the plates 5 is 90° out of phase with respect to that impressed on the plates 6 since the former is equal to the drop across a condenser, whereas the latter is equal to the drop across a resistance. The alternating E. M. F. across plates 5 tends to produce vertical oscillations of the beam and, at the same time, the E. M. F. across plates 6 tends to produce horizontal oscillations. The beam is therefore caused to describe a hollow conically shaped figure the projection of which on the spokes of target 7 is a circle. This may be shown mathematically, as follows:

Let

$x = a \sin pt =$ voltage component applied to plates 6

and

$y = a \sin\left(pt + \frac{\pi}{2}\right) =$ voltage component applied to plates 5.

Then

$$x^2 = a^2 \sin^2 pt$$

and

$$y^2 = a^2 \sin^2\left(pt + \frac{\pi}{2}\right) = a^2 \cos^2 pt$$

$$x^2 + y^2 = a^2 \; (\sin^2 pt + \cos^2 pt)$$

but

$$\sin_2 pt + \cos_2 pt = 1.$$

Therefore

$$x^2 + y^2 = a^2 = \text{a circle.}$$

Electrons impinging upon the spokes of the target in succession during one revolution of the beam, that is, during one complete cycle of the input E. M. F. impressed upon the deflector plates, render the target, and therefore the control electrode of space discharge tube 15, negative periodically depending on the number of spokes on the target. As in accordance with a well known principle each of these negative charges on the control electrode of tube 15 tends to decrease the current in the anode circuit with the result that there is induced in the secondary winding 20 an alternating current whose frequency is equal to the product of the original frequency impressed upon the deflector plates and the total number of spokes on the target 7.

Either odd or even harmonics of the fundamental wave are produced depending on the number of spokes. The wave produced will be substantially a sine wave inasmuch as the control electrode is energized during a period equal to that in which it is not energized, in view of the fact, as pointed out above, that the arc traversed by the beam on each spoke is equal to the arc traversed between adjacent spokes.

The sequence of the steps in the production of the harmonic current induced in the secondary winding of transformer 19 by a system similar to that shown in Fig. 1 is illustrated by curves B, B′, C and C′ of Fig. 4. The reference letter A in Fig. 4 designates the fundamental wave applied to the deflector plates. Curves B and B′ represent the frequency of the anode current and the frequency of the current in the transformer secondary, respectively, when the target is equipped with eight projections; and curves C and C′ similarly represent the frequency of the anode current and the frequency of the current in the transformer secondary when the target has nine projections. In both cases the numerals refer to the individual spokes on the target. The order of the harmonic produced by this arrangement it will be observed is determined solely by the number of projections on the target.

Desired variations in the harmonic frequency may be easily and quickly achieved by replacing the tube in use with a tube whose target possesses the desired number of spokes. The necessity of changing the tubes in order to obtain a different harmonic may be eliminated, however, by designing a single target to have a different number of spokes at different radii and properly varying the radius of the beam traced. For example, a single concentric target may be constructed to have three spokes at a .5 cm. radius, five at 1 cm. and seven at 1.5 cms. in which case the third, fifth or seventh harmonic may be produced by suitably varying either the deflector plate or anode voltage to produce the proper size circle.

Fig. 2 shows an arrangement similar to that of Fig. 1 except that in Fig. 2 two targets and a push-pull amplifier are utilized. The reference numerals 1 to 6 and 8 to 14 in Fig. 2 denote elements whose functions are similar to the elements having corresponding designations in Fig. 1. The reference numerals 22 and 23 designate two similar targets positioned in parallel planes in the path of the electrons at right angles to the normal direction of the beam. For the purpose of illustration the targets are shown relatively far apart, whereas, in practice, they are preferably separated from each other only by the minimum practicable spacing in order that the beam will trace substantially the same size circle on all targets. With the targets close together any variation in the amplitude of the impressed wave will change the size of the trace on all targets an equal amount with the result that undesired amplitude variations will not cause frequency distortion in the output. The targets may be spaced relatively far apart, however, provided that they are symmetrical in design. It is immaterial as to what their actual diameters are so long as the spokes of each target intercept the beam. Of course, with an appreciable spacing between the targets considerations of economy of material require the diameters to increase with the distance from the source of the beam.

The push-pull amplifier comprises space discharge tubes 24 and 25 each of which has the usual cathode, anode and control electrode. The control electrodes of these tubes are directly connected to targets 22 and 23, respectively. Associated with space discharge tube 24 is an input circuit which includes a grid leak resistance 26 and an output circuit which includes the primary winding 28 of output transformer 30. Similarly, the input circuit of tube 25 includes resistance 27 and the output circuit includes winding 29 of transformer 30. The secondary winding 31 may be connected to another amplifier or to a work circuit. Included also in the output circuit of each tube is battery 17 which has its positive terminal connected to the anodes of both tubes. Energy for heating the cathode of both tubes is supplied from battery 16.

The cathode ray tube produces an electronic stream which is deflected so as to produce a hollow conical envelope in the manner described in connection with Fig. 1, and in tracing a circular path on the targets the beam impinges alternately on the spokes of targets 22 and 23 and thus alternately energizes the control electrode of each of tubes 24 and 25 at a frequency proportionl to the number of spokes on each target.

The amplifier operation is similar to that of the ordinary push-pull amplifier. When the control electrode of one tube is rendered negative by the charge on the associated target, the control electrode of the other tube is relatively positive. The fundamental frequency produced in the anode circuits of each of tubes 24 and 25 is therefore that multiple of the frequency of the potential originally supplied to the deflector plates measured by the product of the original frequency and the number of spokes on the respective target. This fundamental frequency therefore is an odd or even harmonic frequency of the fundamental wave on the deflector plates depending on whether each target contains an odd or an even number of spokes. However, as explained below, this fundamental is not transmitted to the work circuit.

Inasmuch as the primary windings 28 and 29 are differentially related to the secondary winding 31 when taking the relative phases of the currents flowing therethrough the fundamental and odd harmonic frequencies present in each of the tube anode circuits are balanced out and only even harmonics of the wave originally supplied to transformer 10 are eventually transmitted to the work circuit through transformer 30. Consequently, in this system the order of harmonic produced is always even no matter whether the targets have an odd or even number of spokes.

Referring again to Fig. 4, the harmonic frequencies produced by an arrangement similar to that shown in Fig. 2 are illustrated in curves D, D′, E and E′, A being the fundamental wave. Curve D represents the combined anode currents of both tubes, resulting from the use of two targets, each having four spokes. The numerals above the "O" line refer to the spokes on one target and those below this line refer to the spokes on the other target. Anode currents of the frequency represented by curve D, which also represents the fourth harmonic of the fundamental wave A, are balanced out because of the differential relationship between the primary windings of transformer 30; and the lowest frequency transferred to the secondary winding 31 is the second harmonic of the anode frequency, that is, the eighth harmonic of the fundamental wave which is represented by curve D′. In a similar manner curve E illustrates the frequency of the combined anode currents of both tubes obtained by using two targets each equipped with three spokes; and curve E′ shows the ultimate frequency transmitted to the work circuit which in this case is the sixth harmonic of the fundamental wave. Thus, in the arrangement shown in Fig. 2 only even harmonics of the fundamental wave are available for use in the work circuit.

Fig. 3 represents a modification of the invention for producing a greater frequency multiplication and incidentally, either odd or even harmonics of the fundamental wave. As in Fig. 2 the reference numerals 1 to 6 and 8 to 14 designate elements which perform the same functions as those similarly designated in Fig. 1. Three parallel targets designated 32, 33 and 34 and similar in construction, are interposed in the path of the electronic beam which is caused to revolve in the manner described above. The targets are shown spaced from each other but in the preferable arrangement they should be relatively close together as discussed in connection with the device of Fig. 2. As shown in the developed view in Fig. 3A the spokes of targets 33 and 34 are positioned in respect to target 32 and to each other so that the revolving beam will impinge on the three targets in succession.

Space discharge tubes 35, 36 and 37 each includes an anode, cathode and a control electrode; the control electrodes of these tubes are connected respectively to targets 34, 33 and 32. The high resistances 41, 42 and 43 connected in the input circuits of tubes 35, 36 and 37, respectively, permit electrons to escape from the control electrodes to the cathodes of the respective tubes.

Energy for heating the cathodes of all three tubes is supplied from battery 16 and a positive potential is impressed on the anode of each tube through the common transformer winding 38 by means of battery 17 connected in the output circuit of all three tubes. The anodes are shown directly connected together to effect an additive output relationship but it is to be understood that three separate transformer primary windings each connected to a separate anode may be substituted in place of the arrangement shown without affecting the result. Transformer 39, including windings 38 and 40, serves to transfer energy from the space discharge tube output circuits to the work circuit.

The beam is caused to revolve in the manner explained in connection with Figs. 1 and 2 and consequently the control electrodes of tubes 35, 36 and 37 become negatively charged in succession because of the staggered relationship of the targets. Each separate charge, however, causes a corresponding decrease in the current flowing through winding 38 so that the current through this winding possesses a fundamental frequency equal to the product of the fundamental wave supplied to transformer 10 and the total number of spokes on all targets. Inasmuch as the total number of spokes may be an odd or even number either odd or even harmonics of the fundamental wave may be obtained as the fundamental frequency in winding 38. This fundamental frequency is induced in winding 40 for utilization in the work circuit together with its harmonics in all cases except in the single instance when two targets only are used, in which case the even harmonics will be balanced out.

Curves F and F′ of Fig. 4 show the frequency of the anode current and the frequency of the current in winding 40, respectively, when three targets of four spokes each are employed. The numerals indicate the order in which the individual spokes on the three targets become energized. It will thus be seen that the frequency represented by curve F′ is the twelfth harmonic of the fundamental wave A, twelve being the total number of spokes on the three targets. Curves G and G′ illustrate the corresponding frequencies obtained when three targets of three spokes each are employed. In this case the fundamental frequency in winding 40 represented by curve G′ is the ninth harmonic of the fundamental wave A. Either odd or even harmonics are therefore obtained by this arrangement, the odd harmonics being a multiple of the number of targets.

In the various embodiments of the invention described in connection with Figs. 1 to 3 and the associated curves of Fig. 4 the cathode ray tube is shown equipped with deflector plates for generating a beam and causing it to revolve conically. The invention, however, is not limited to this specific means for deflecting the beam, but rather includes broadly any means for deflecting an electronic beam such as, for example, electromagnetic coils located adjacent to the stream, one pair of coils being at right angles to another pair and energized by a current in quadrature.

It should also be understood that the application of the invention is not intended to be confined to the type of cathode ray tube shown in these specific embodiments but includes broadly any electron-emitting tube of the evacuated or gas-filled type.

What is claimed is:

1. The method of producing harmonic frequencies having a sine wave form substantially utilizing an electron beam and a conductive element containing several projections which comprises causing the beam to impinge on and flow by the projections alternately for equal time intervals during each cycle of the fundamental wave and utilizing the electrons absorbed by said element to vary the current in an external circuit.

2. The method of producing harmonic frequencies having a sine wave form substantially utilizing a cathode ray, a conductive element containing a plurality of projections and an amplifier, which comprises moving the ray at a speed determined by the frequency of the fundamental wave, causing it to traverse and avoid the projections alternately during equal time intervals cyclically, and transferring the electrons on said projections to the control electrode of said amplifier.

3. The method of producing harmonic frequencies having a sine wave form substantially utilizing a cathode ray, an absorbing means, means for deflecting the cathode ray, and an energized space discharge tube, which comprises deflecting the ray cyclically in accordance with the fundamental wave, absorbing and not absorbing energy therefrom alternately during equal time intervals at a

frequency corresponding to the desired harmonic, and transferring the absorbed energy to the control electrode of the space discharge tube.

4. The method of producing harmonic frequencies having a sine wave form substantially of a fundamental wave utilizing a cathode ray, a plurality of conductive elements each containing a plurality of projections, and a plurality of space discharge tubes, which comprises causing the ray to impinge on all projections of the elements alternately for successive equal time intervals during one cycle of the fundamental wave, transferring the energy absorbed by each element to the control element of a different discharge tube, and combining the output current of said tubes.

5. In combination with means for producing a cathode ray and means for varying the direction of said ray cyclically, additional means comprising conductive elements connected to each other through a path of substantially zero impedance and arranged to intercept and avoid said ray alternately during equal time intervals, and means controlled by said elements for regulating the flow of energy in a separate circuit.

6. In combination, a device for producing a stream of electrons, means for varying the direction of said stream cyclically, a target included in said device and having a plurality of projections, said projections being positioned to receive and avoid said electrons alternately and in succession during equal time intervals, and means connected to said target for varying the current in an external circuit.

7. In combination, means including a cathode and an anode for obtaining an electron stream, potential means including deflector plates adjacent to said stream for cyclically deflecting the stream, means comprising a conductive target having a plurality of projections located in the path of said stream, the width and spacing of the projections in said path being equal, said target connected to the control electrode of a space discharge amplifier having an output circuit.

8. In combination, a cathode ray tube, means associated therewith for causing the ray produced to revolve conically at a predetermined rate, a target included in said tube and having a plurality of radial projections in the path of the ray, the width and spacing of the projections in said path being equal, a space discharge tube having its control electrode connected to said target, and an output circuit associated therewith.

9. In combination, means for producing an electron beam, means for cyclically deflecting said beam in accordance with the frequency of a fundamental wave, means comprising parallel targets each having a plurality of protuberances in the path of the beam, the protuberances of adjacent targets being staggered in respect to each other, and potential responsive means associated with a common work circuit connected to each of the targets.

10. In combination with means for producing an electronic stream, means for causing the stream to revolve conically at a predetermined rate, means for continually absorbing energy from said stream comprising a plurality of parallel targets each containing a plurality of radial projections arranged to be successively energized, and separate means connected to each target for varying the flow of energy in an external circuit.

11. In combination, a Braun tube adapted to produce a ray revolving in synchronism with a fundamental wave, means for causing the wave to impinge in succession on a plurality of targets, a plurality of thermionic devices having differentially connected input circuits and output circuits associated with a common work circuit, each of the said devices being controlled by one of the targets.

12. In a frequency multiplication system, a cathode ray tube, means for producing a cathode ray therein, a source of variable potential, means for obtaining quadrature potentials therefrom, means for revolving the ray conically comprising a plurality of deflector plates adjacent to the ray and energized by the quadrature potential, a plurality of electrodes arranged to successively absorb energy from the ray, a plurality of thermionic devices each of which is controlled by one of the electrodes, the anode circuits of the said devices being associated with a common work circuit.

In witness whereof, I hereunto subscribe my name this 2 day of August, 1929.

WARREN A. MARRISON.