

Jan. 13, 1942.

K. RATH

2,269,688

ELECTRONIC MODULATOR

Filed Feb. 24, 1941

2 Sheets-Sheet 1

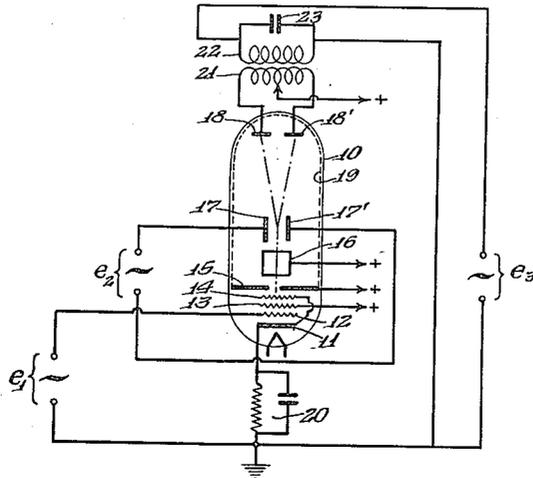


FIG. 1.

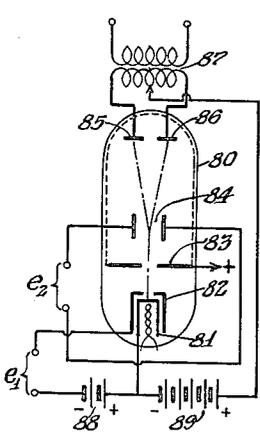


FIG. 8.

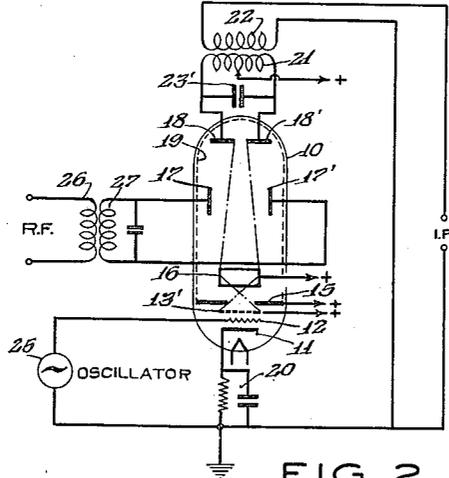


FIG. 2.

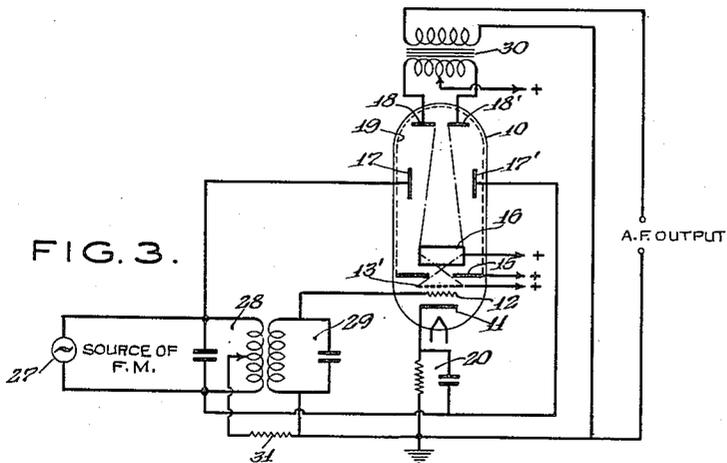


FIG. 3.

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2 Sheets-Sheet 2

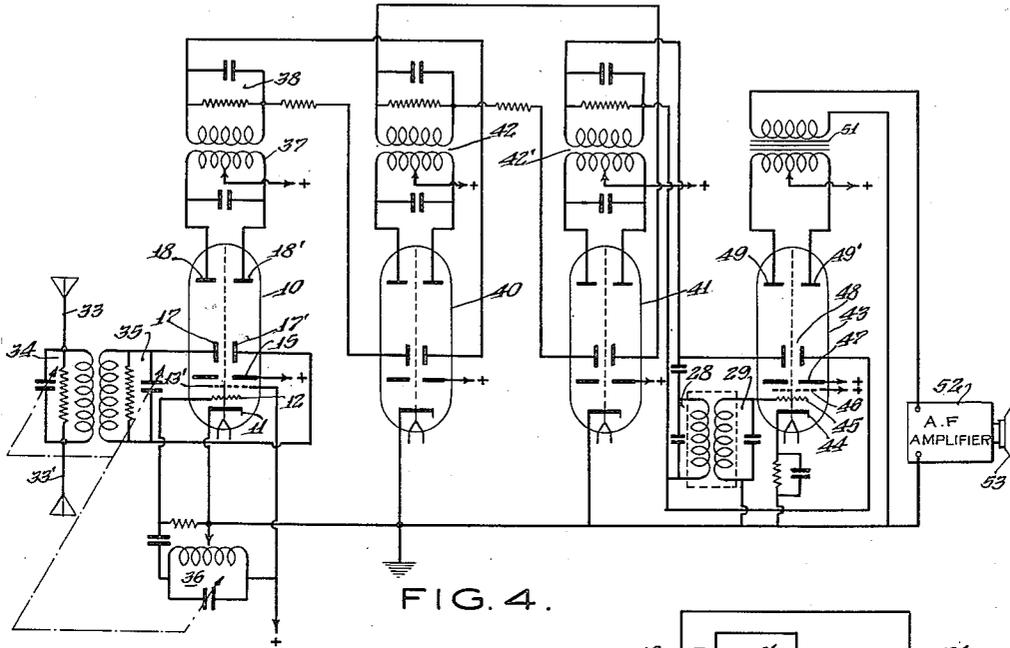


FIG. 4.

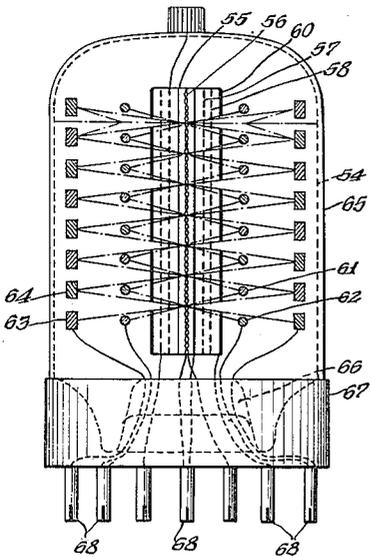


FIG. 5.

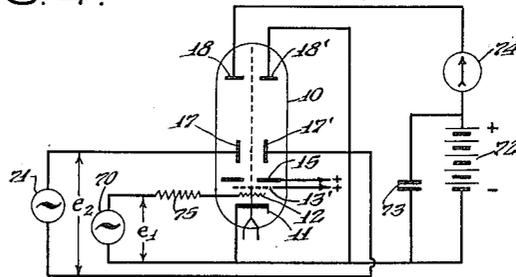


FIG. 6.

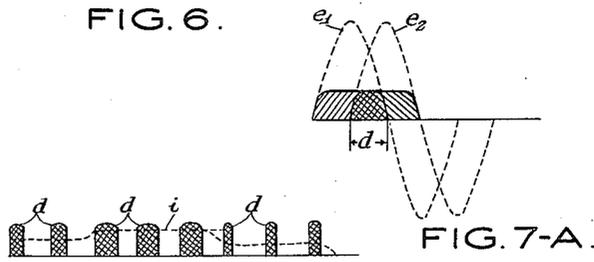


FIG. 7-B.

FIG. 7-A.

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ELECTRONIC MODULATOR

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Application February 24, 1941, Serial No. 380,103

16 Claims. (Cl. 179—171.5)

This application is a continuation-in-part carved out from U. S. application Serial No. 367,180, filed November 26, 1940, entitled "Frequency modulation system."

The present invention relates to electronic mixers or modulators and a method of operating the same serving generally for combining a pair of alternating currents or potentials into output energy having an amplitude varying in accordance with the product of said potentials and including a term or component having special characteristics for utilization in a subsequent output circuit or translating device. Modulators or mixers of this type may serve e. g. to amplitude modulate a radio frequency wave in accordance with a lower frequency modulating wave in a radio or other signal transmitter, for combining waves of different frequency to produce a sum or difference frequency wave as in the case of the mixer or first detector in a superheterodyne receiving system, or for combining alternating current waves of like frequency but having a varying phase relation into energy having an amplitude varying proportionately to said phase relation in a phase or frequency discriminator or indicator device and for various other uses and applications.

The known electronic mixers or modulators of the above general character usually comprise a pair of control grids located at different points of an electron discharge stream and being preferably shielded from each other by a positively biased screen grid. Each of the potentials to be combined or intermodulated is impressed upon one of said control grids whereby due to the dual control of the electron stream and with the proper operating and biasing potentials being applied to the electrodes of the tube, the average output or plate current will include a term proportional to the product of said control potentials from which a desired component may be segregated by suitable selective means for utilization in a subsequent circuit or output device.

In modulators of this type difficulties have been experienced in the past due to mutual reaction between the potentials applied to the control grids of the tube through the interelectrode capacity between the grids despite the shielding effect of the screen grid and through space charge coupling due to the effect of a so-called virtual cathode produced between the grids by the accelerating and subsequent deceleration action on the electron stream by the positive and negative electrostatic fields of the screen grid and the control grid on the side of the screen

next to the anode, respectively. This defect becomes especially apparent and objectionable as the operating frequency is increased as in the case of short and ultra short waves since both the electrostatic as well as the space charge coupling effect increases directly as a function of the frequency. Such reaction between the control potentials not only greatly impairs the operating stability of the system but may cause considerable distortion by affecting the phase relation between the control potentials, especially in case of phase or frequency discriminators serving to convert phase or frequency changes into corresponding amplitude variations.

Accordingly, an object of the present invention is to provide an electronic mixer or modulator wherein a pair of input energies are combined into modulated energy substantially without undesirable mutual interaction between said input energies except in producing the desired output energy varying proportionately to their product.

Another object is to provide a modulator of high operating stability and efficiency for producing modulated energy from a pair of given alternating input currents or potentials.

A further object is to provide a highly stable and efficient modulator especially suited for combining potentials or currents of like frequency and varying phase relation into output energy having an amplitude varying substantially in proportion to said phase relation whereby minute phase, frequency, capacity or inductance changes may be converted into corresponding large current changes in a most simple and reliable manner.

These and further objects as well as aspects of the invention will become more apparent from the following detailed description taken with reference to the accompanying drawings forming part of this specification and wherein

Figure 1 is a diagram representing a basic modulator circuit embodying the principles of the invention,

Figure 2 shows a modification of Figure 1,

Figure 3 illustrates the use of the invention as a phase or frequency discriminator,

Figure 4 is a diagram of a superheterodyne frequency modulation receiving system embodying electronic mixer devices according to the invention in both the frequency changer and discriminator stages of the receiver,

Figure 5 is a schematic diagram illustrating a tube construction for the purpose of the invention,

Figure 6 is a circuit diagram illustrating an improved and simplified phase or frequency discriminator constructed in accordance with the invention,

Figures 7A and 7B are theoretical diagrams 5
explanatory of the function of the discriminator according to Figure 6,

Figure 8 illustrates a further modification of the invention.

Like reference characters identify like parts throughout the different views of the drawings.

With the aforementioned objects in view, the invention generally involves the use of an electron discharge stream having a first amplitude or intensity controlled portion subjected to the effect of a first input potential and a further concentrated and deflection controlled portion substantially in series relation to said first portion and subjected to control by a second input potential to produce a component of the average output current having an amplitude varying substantially according to the product of said control potentials. In this manner, by subjecting different portions of a common electron stream to a different type of control (amplitude or intensity control on the one hand and deflection control on the other hand) mutual interaction between the input circuits or control effects is substantially eliminated resulting in a highly stable operation and greatly increased efficiency and sensitivity of the system in combining a pair of input energies into common output energy having an amplitude varying substantially in proportion to the product of said input energies.

Referring more particularly to Figure 1, there is shown a basic modulator circuit embodying the principles of the invention and comprising an electron discharge tube 10 having a source of electrons or cathode 11, an electrostatic control grid 12, a positive or screen grid 13 biased at high positive potential with respect to the cathode, a further grid 14 operated substantially at cathode potential, an apertured focussing anode 15, a further annular shaped concentration anode 16, a pair of electrostatic deflecting plates 17 and 17', and a pair of anodes or targets 18 and 18', all arranged in the order named with respect to the cathode. The electrodes 11, 12 and 13 represent an ordinary triode whereby an output current will be passed through the external circuit connected to the grid 13 having an amplitude varying as a function of the potential e_1 impressed upon the grid 12 controlling the effect of the electron space charge on the diffuse or substantially non-concentrated space current passing from the cathode to the grid 13 in a manner well understood. Item 20 represents a capacity shunted biasing resistance inserted in the cathode-to-ground lead of the tube to provide suitable negative biasing potential for the control grid 12 in accordance with standard practice. The purpose of the grid 14 operated in the example shown at cathode potential and connected for this purpose directly to the cathode but which, if desired, may be biased at a potential negative to the cathode by providing a suitable biasing source, is to produce a virtual cathode or concentrated electron space charge adjacent to the aperture or opening of the focusing anode 15 to serve as a source for a concentrated electron beam produced in the remaining section of the tube and impinged with variable cross-sectional areas upon the targets 18 and 18' by the action of a suitable deflecting arrangement, in the example illustrated the deflecting plates 17 and 17'. 75

The deflection of the electron beam is effected by a second potential e_2 impressed upon the deflecting plates 17, 17'. The internal surface of the beam portion of the tube is preferably provided with a grounded metallic coating 19 to prevent the formation of disturbing wall charges. The electron gun or beam generating arrangement may be modified in any desired manner in accordance with known practice so as to obtain a concentrated electron beam varying cross-sectional portions of which will be impinged upon the targets 18 and 19 in accordance with variations of the deflection control potential e_2 in such a manner that the output current passing through an associated output circuit will vary in predetermined relation to the control potential variation in a manner well known in deflection control electron tubes. In order to utilize both half waves of the deflecting potential, the targets 18 and 18' are connected to the opposite ends of a suitable load impedance in the example shown a tuned transformer having a primary winding 21 and a secondary winding 22 shunted by a tuning condenser 23, and the positive pole of an output current source indicated by the plus sign is connected to the mid point of the primary 21, the negative pole of the current source being returned to the cathode in a manner well understood. The grid 13 and the focusing electrodes 15 and 16 are suitably energized by connecting them to points of a suitable high potential source such as a battery or voltage divider in accordance with standard practice.

From the foregoing it is seen that in a tube of the type described, the electron stream emitted from the cathode 11 has a first substantially non-concentrated portion subject to intensity or amplitude control in accordance with the first input potential e_1 which first portion is followed by a concentrated or beam portion subject to deflection control in accordance with a second potential e_2 , whereby as a result of the dual control action the output current through the primary 21 will include a component varying in amplitude substantially proportionately to the product of the potentials e_1 and e_2 . Thus, assuming that e_1 represents a high frequency (carrier) signal potential and e_2 a lower frequency modulating potential, modulated high frequency currents will be developed in the primary 21 transmitted to the secondary 22 tuned in this case to the carrier frequency from which a corresponding amplitude modulated voltage e_3 may be derived for further utilization. Due to the complete separation of the discharge sections by the virtual cathode and the different character of both controls mutual interaction is substantially eliminated resulting in a highly stabilized operation substantially independent of the frequencies and other characteristics of the modulating and modulated potentials as will be evident from the above.

Referring to Figure 2 there is shown a modification of an electronic mixer circuit of the type according to the invention. According to this embodiment, the grid 14 is omitted and a single positively biased grid 13' provided in addition to the control grid 12. Grid 13' is coated with a suitable substance capable of causing profuse secondary electron emission by impact of the primary electrons emitted from the cathode 11. As a result, a dense cloud of both primary and secondary electrons or virtual cathode will be formed adjacent to the aperture of the focusing anode 15 serving as a source for the electron gun in substantially the same manner as in the case

of Figure 1. There is also illustrated in Figure 2 the employment of a mixer tube according to the invention as a frequency changer or first detector in a superheterodyne or any other signaling system. For this purpose input radio frequency (RF) signals are impressed upon the deflecting plates 17 and 17' by way of a tuned coupling transformer having a primary 26 and tuned secondary 27. A further potential of different frequency produced by a local oscillator 25 is impressed upon the control grid 12 of the intensity control section whereby by virtue of the dual control or intermodulation effect of the tube signal currents of intermediate frequency will be developed in the primary 21 of the output transformer tuned to the intermediate frequency (IF) by the condenser 23'. The function of the electrostatic control grid 12 and the deflecting plates 17 and 17' may be interchanged without substantially affecting the results obtained, that is the input signal potential may be impressed upon the grid 12 and the local oscillating voltage applied to the deflector plates 17 and 17'.

Referring to Figure 3 there is illustrated the use of an electronic modulator of the invention in a phase or frequency discriminator for converting phase, frequency, inductance or capacitance changes into corresponding amplitude variations of an electric current. The discriminator shown is of the phase shift type comprising substantially a phase shifting network to produce a pair of potentials having a phase relation varying as a function of the phase, frequency, inductance, or capacitance changes to be translated or detected, and means for combining or intermodulating said phase shifted potentials to obtain an output current varying according to their product. The average value of said output current will include a term having an amplitude varying substantially proportionately to the phase frequency, capacitance, or inductance changes to be detected. According to the present improvement, by employing an electronic mixer of the type described, mutual interaction between the potentials of varying phase relation is completely eliminated thus preventing any spurious phase shifts from affecting the accuracy and stability of the converter and resulting in a highly efficient and reliable discriminator substantially independent of the frequency and other characteristics of the input signals. In Figure 3, item 27 represents a source of variable frequency such as a circuit traversed by frequency modulated carrier currents connected to a phase shifting network in the example shown comprising a double tuned transformer or band-pass filter having a primary 28 and a secondary 29. As is well known, such a filter or network with the primary 28 and secondary circuit 29 tuned to a particular (carrier) frequency supplies a pair of voltages developed across the primary and secondary windings having a phase relation varying in proportion to the departure of the impressed frequency from the frequency to which the network is resonant. Thus, if the impressed frequency equals the tuning frequency of the network, the voltages across the primary and secondary windings will be 90° out of phase with respect to each other and this normal phase relation will increase above or decrease below 90° as the impressed frequency deviates in either direction from the resonant frequency. The variably phase shifted voltages are impressed upon the control elements of the tube 10 which is of substantially similar type to that shown in the pre-

vious figures. In the example shown the primary voltage is impressed upon the deflecting plates 17 and 17' while the secondary voltage is applied to the grid 12 and cathode of the amplitude control section in a manner understood from the above. The mid point of the primary winding may be connected to ground through a resistance 31 to insure equal and stable deflecting potentials for the electron beam. A detailed analysis shows that by combining energies of like frequency but varying phase relation by means of a device adapted to produce output energy having an amplitude proportional to the product of said energies, the average output energy obtained will include a term or component varying substantially proportionately to the phase relation between the input energies being combined. It is found that this variable output component is proportional to the cosine of the phase angle between the input energies or for practical purposes directly proportional to the phase angle within a certain operating range of deviation from a particular (carrier, center) frequency. Thus, if the impressed frequency equals the resonant frequency of the phase shift network resulting in a 90° phase relation between the controlling energies or voltages, the variable component of the steady or quiescent output current will be zero and will increase in either direction in accordance with the sense and in proportion to the extent of departure of the impressed frequency from the resonant frequency of the phase shifting circuit.

As is understood, a system of this type may serve as a phase discriminator or converter by applying a potential of standard phase to one of the controlled elements and exciting the other control element by a potential whose relative phase angle is to be determined. Alternatively, the system may serve as an indicator or detector of small changes of inductance or capacity. For this purpose the frequency impressed from the source 27 is maintained constant and the tuning adjustment of the resonant or phase shifting circuit varied by controlling an inductance or capacity element forming an effective tuning element of the circuit. As a result, the relative detuning between the impressed frequency and the resonant frequency of the circuit will be manifested in a corresponding change in the average output current substantially proportional to the initial capacity or inductance variation as will be readily understood from the foregoing.

If the system of Figure 3 is used as a detector or demodulator in a frequency modulation receiver as indicated in the drawings, there is provided in the output circuit connected to the targets 18 and 18' a load impedance adapted to develop output voltage at modulating frequency such as an audio frequency transformer 30 supplying an audio frequency output voltage. If the frequency changes of the source 27 are of a different rate or character, such as in the case of gradual and progressive variations due to temperature and other effects, the load impedance in the output circuit preferably takes the form of a resistance adapted to develop an output voltage varying at the rate of the input frequency fluctuations. Slow or progressive frequency variations are encountered in case of automatic frequency control for radio transmitters and receivers, in frequency monitoring devices or capacity and inductance checking or measuring systems. As is understood, the relation of the control electrodes may be reversed, that is the primary voltage in Figure 3 may be impressed upon the grid 12 and

the secondary voltage applied to the deflecting plates without affecting the operation and final results obtained.

Referring to Figure 4, there is shown a diagram of a complete frequency modulation receiver embodying a pair of dual control tubes according to the invention serving both as a frequency changer or mixer and discriminator or detector of the frequency modulated signals. Frequency modulated signals intercepted by a suitable receiving antenna such as a dipole system 33, 33' are impressed by way of a resonant transformer having a primary 34 and a secondary 35 upon the deflecting plates 17 and 17' of a frequency changer or first detector of substantially the same type as shown in Figure 2. In place of a separate local oscillator as shown in Figure 2, the amplitude control section of the tube is utilized to generate self-excited oscillations by the provision of a regenerative circuit arrangement comprising a tunable circuit 36 operatively connected to the control grid 12 and positively biased grid 13' to maintain sustained electrical oscillations in a manner well understood and to produce a space charge or virtual cathode adjacent to the opening of the focusing anode 15 varying in accordance with the oscillating frequency determined by the tuning of the resonant circuit 36. The tuning element of the latter is suitably ganged and tracked with the tuning elements of the coupling transformer 34, 35 to maintain a substantially constant difference between the received and local oscillating frequency in a manner customary in superheterodyne systems. There are produced in this manner in the output circuit of the tube currents of intermediate frequency equal to the difference between the received and local oscillating frequency which are segregated by means of a resonant transformer having a primary 37 and secondary 38 and being tuned to the intermediate frequency. The intermediate frequency signals are further amplified by a pair of intermediate frequency amplifier tubes 40 and 41 arranged in cascade and provided with resonant output transformers 42 and 42', respectively. The amplifiers 40 and 41 are of the deflector type as described in the parent application and are advantageously designed and operated to act as limiting devices to remove spurious and other amplitude modulation from the frequency modulated waves so as to deliver a purely frequency modulated voltage to the resonant phase shifting transformer 28, 29 of the frequency discriminator. As described in the parent application, the tubes are designed for this purpose in such a manner that the full cross-sectional area of the electron beam is impressed upon the output or target electrodes at a predetermined fraction of the peak amplitude of the deflecting potentials resulting in a flattening of the peaks of the output currents and removal of amplitude modulation representing static or tube noise and other interfering signals from the frequency modulated waves. In the same manner the frequency converter 10 may be additionally utilized as a limiter and for this purpose is preferably designed and operated in such a manner that the maximum sweep of the electron beam to be expected by the strongest input signal applied to the deflecting plates 17 and 17' will just reach the outer edge of the targets 18 and 18'. Alternatively, in order to render the system substantially independent of the strength of the input signals, the local oscillating potential produced by a separate oscillator may be impressed upon the deflecting plates 17

and 17' while the input signal potential is applied to the control grid 12.

The phase shifted signal potentials produced by the transformer 28, 29 are impressed upon the amplitude and deflection control elements of a mixer or modulator tube 43 having a cathode 44, amplitude control grid 45, secondary emitting anode grid 46, apertured focusing anode 47, electrostatic deflecting plates 48, and target anodes 49 and 49' arranged and operated in substantially the same manner to that shown in Figure 3. The demodulated or audio frequency currents are applied from the output circuit by way of low frequency transformer 51 to an audio frequency amplifier 52 of known construction energizing a suitable output device such as a loud speaker 53.

Referring to Figure 5 there is shown schematically a structure of an electron mixer tube suitable for use with the invention and wherein a plurality of electron discharge beams are provided to cooperate with a common deflecting and output electrode system to enable full utilization of a given discharge space and to decrease size and bulk of the tubes. The tube shown comprises an envelope 65 of glass or metal enclosing a cylindrical indirectly heated cathode 55 provided with a heater 56 and surrounded by a cylindrical amplitude control and anode grids 57, 58, respectively, and a focusing anode 60. The latter is provided with a series of parallel arc-shaped slots to produce flat or fan-shaped electron discharge beams extending radially from the cathode, one above the other. Items 61 and 62 represent a pair of deflecting electrodes in the form of spiral wires of circular or rectangular cross-section equally spaced and isolated from each other, while a pair of similar spiral wires or bands 63 and 64 serve as common output or target anodes for all the fan-shaped electron beams to obtain a common resultant output current. The tube is provided with a suitable base 67 and terminal elements such as prongs 68 electrically connected to the circuit electrodes in a manner well understood.

Referring to Figure 6 there is shown an improved and simplified phase indicator or measuring system utilizing a converter tube according to the invention. The latter which is of substantially the same type as shown in Figures 2 and 3 has its amplitude control grid 12 excited by a source 70 supplying an alternating potential e_1 which may have a fixed or standard phase. The source 70 is connected to the grid of the tube in series with a resistance 75 to produce a negative grid bias as the amplitude of impressed potential increases resulting in a substantial flattening of the discharge current as shown in Figure 7A (hatched area with lines slanting towards the left). A second potential e_2 of varying phase supplied by a source 71 is impressed upon the deflecting plates 17 and 17' and the tube is preferably designed and operated to act as a limiter in the manner described in the parent application so as to flatten the output current above a predetermined fraction of the peak value of the impressed voltage e_2 as shown in Figure 7A (hatched area with lines slanting towards the right). This effect can be obtained by suitably designing the spacing between the electrodes 18 and 18' in relation to the cross-section of the electron beam and in this manner as seen from Figure 7A output current will flow only during the overlapping or cross-hatched period d when both controls by the grid 12 and the deflecting plates 17 and 17' are such as to allow the passage of

the discharge current. In order to enable output current to pass during one half cycle only of the deflecting potential e_1 one of the targets (18') may be omitted or short-circuited to the cathode as shown in the drawing. Similarly to pass current in the diffuse discharge amplitude control section of the tube during the positive half cycle only, the grid 12 is operated at the cut-off point by the proper design or bias of the electrodes. Accordingly, therefore, the current conducting the periods d will vary in accordance with the phase displacement between the impressed potentials e_1 and e_2 and output current impulses d produced by the high potential source 72 bypassed for alternating current by a condenser 73. The average output current i , Figure 7B, may be utilized to actuate a current indicator 74 or to develop a voltage by the provision of a suitable load impedance for further utilization. There is thus provided a highly stable and sensitive phase indicating or translating device which may be employed as a frequency discriminator or capacitance and inductance meter if the potentials e_1 and e_2 are supplied from a phase shifting network of any suitable type such as shown in Figures 3 and 4.

In Figure 8 there is shown a further modification of the invention utilizing combined amplitude and deflection control for producing modulated output energy from a pair of given input potentials. The tube 80 shown in this embodiment comprises an indirectly heated cathode 81 enclosed by a so-called Wehnelt or concentration cylinder 82 biased negatively with respect to the cathode by the aid of a suitable biasing source such as a battery 88 and which also serves as an intensity control element of the electron space current impinged upon the apertured focusing anode 83. Item 84 represents the deflecting plates and 85 and 86 are the output or target electrodes connected to the transformer 87 whose primary mid-point is connected to the high potential source 89. By superimposing upon the steady bias of the cylindrical electrode 82 a variable voltage e_1 and applying a further voltage e_2 to the deflecting plates 84, a product term of said voltages will be produced in the output circuit and in this manner the system may be utilized for a variety of purposes depending on the character of the control voltages e_1 and e_2 as will be evident from the foregoing.

It will be evident from the foregoing that the invention is not limited to the specific details, circuits and arrangements of parts shown and disclosed herein for illustration but that the underlying general thought and principle of the invention will be susceptible of numerous variations and modifications coming within the broader scope and spirit of the invention as defined in the appended claims. The specification and drawings are accordingly to be regarded in an illustrative rather than a limiting sense.

I claim:

1. A system for mutually intermodulating a pair of alternating current energies comprising an electron discharge tube provided with means for producing an electron space current, means for initially controlling the intensity of said space current in accordance with one of said energies, means to form a virtual cathode from the controlled space current means for concentrating electrons supplied by said virtual cathode into a beam of predetermined cross-section, means for deflecting said beam cross-wise to its normal axis, anode means arranged for impingement by

said beam, further means for controlling said deflecting means in accordance with the other of said energies, an output circuit connected to said anode means, and means in said output circuit for utilizing a component of the output current being a function of the product of said first and second energies.

2. A system for mutually intermodulating a pair of alternating current voltages comprising an electron discharge tube provided with means for producing an electron space current, an electrostatic control grid excited by one of said voltages for initially controlling the intensity of said space current, means to form a virtual cathode from the controlled space current, means for concentrating electrons supplied by said virtual cathode into a beam of predetermined cross-section, deflecting means excited by the other of said voltages for deflecting said beam cross-wise to its normal axis, anode means arranged for impingement by said beam, an output circuit connected to said anode means, and means in said output circuit for utilizing a component of the output current being a function of the product of said voltages.

3. A system for mutually intermodulating a pair of alternating current voltages comprising an electron tube provided with means for producing an electron discharge stream, an electrostatic control grid excited by one of said voltages for initially controlling the intensity of said stream, means to form a virtual cathode from the controlled stream, means for focussing electrons supplied by said virtual cathode into a beam of predetermined cross-section, an electrostatic deflecting arrangement excited by the other of said voltages for deflecting said beam cross-wise to its normal axis, anode means arranged for impingement by said beam, an output circuit connected to said anode means, and means in said output circuit for utilizing a component of the output current being a function of the product of said alternating voltages.

4. A system for mutually intermodulating a pair of electrical energies comprising an electron tube provided with means for producing an electron discharge stream having a first substantially diffuse portion in series with a concentrated portion forming a beam of predetermined cross-section, said means including means to form a virtual cathode between said diffuse discharge portion with said concentrated discharge portion, means for controlling the intensity of said diffuse discharge portion in accordance with one of said energies, anode means arranged for impingement by said electron beam, further means for deflecting said beam in accordance with other of said energies, an output circuit connected to said anode means, and means in said output circuit for utilizing a component of the output current being a function of the product of said energies.

5. A system for mutually intermodulating a pair of alternating current input voltages comprising an electron discharge tube provided with a cathode, a control grid and a perforate accelerating anode, means for exciting said control grid by one of said voltages to correspondingly vary the intensity of the electron discharge current emitted from said cathode, means to form a virtual cathode adjacent to said anode focussing means for concentrating electrons supplied by said virtual cathode into a beam of predetermined cross-section, a deflecting arrangement excited by the other of said voltages for deflect-

ing said beam cross-wise to its normal axis, anode means arranged for impingement by varying fractional cross-sectional areas of said electron beam in accordance with its excursions from said normal axis, an output circuit connected to said anode means, and means in said output circuit for utilizing a component of the output current being a function of the product of said input voltages.

6. A system for mutually intermodulating a pair of alternating current input voltages comprising an electron discharge tube provided with a cathode, a control grid, and a perforate anode, means for exciting said control grid by one of said voltages to correspondingly vary the intensity of the electron current emitted from said cathode, means to form a virtual cathode adjacent to said anode focussing means for concentrating electrons supplied by said virtual cathode into a beam of predetermined cross-section, a deflecting arrangement excited by the other of said voltages for deflecting said beam in either direction cross-wise to its normal axis, a pair of targets arranged to be impinged by varying fractional cross-sectional areas of said beam by its excursions during the positive and negative half cycles of the applied deflecting voltage, a load impedance having its opposite ends connected to said targets and having its mid point connected to the positive pole of a high potential source, said load impedance being adapted to develop an output voltage being a function of the product of said input voltages.

7. A system for mutually intermodulating a pair of alternating current input voltages comprising an electron discharge tube provided with a cathode, a control grid and a first perforate anode, means for exciting said control grid by one of said input voltages to correspondingly control the intensity of the electron current emitted from said cathode, further means for producing a virtual cathode on the side of said anode away from said cathode, means for concentrating the electrons supplied by said virtual cathode into a beam of predetermined cross-section, a deflecting arrangement excited by the other of said input voltages for deflecting said electron beam cross-wise to its normal axis, anode means arranged for impingement by varying fractional cross-sectional areas of said beam, an output circuit connected to said anode means, and means in said output circuit for utilizing a component of the output current being a function of the product of said input voltages.

8. A system for mutually intermodulating a pair of alternating current input voltages comprising an electron discharge tube provided with a cathode, a control grid and a first perforate anode, means for exciting said control grid by one of said input voltages to correspondingly control the intensity of the electron current emitted from said cathode, a further decelerating grid arranged on the side of said anode away from said cathode to produce a virtual cathode in the region between said anode and decelerating grid, means for concentrating the electrons supplied by said virtual cathode into a beam of predetermined cross-section, means controlled by the other of said input voltages for deflecting said electron beam in a direction cross-wise to its normal axis, further anode means arranged for impingement by varying fractional cross-sectional areas of said electron beam in accordance with its excursions from said normal axis, an output circuit connected to said anode means,

and means in said output circuit for utilizing a component of the output current being a function of the product of said input voltages.

9. A system for mutually intermodulating a pair of alternating current input voltages comprising an electron discharge tube provided with a cathode, a control grid and a first perforate anode, means for exciting said control grid by one of said input voltages to correspondingly control the intensity of the electron current emitted from said cathode, said anode forming a secondary electron emitter to produce a virtual cathode on the side thereof away from said cathode, focussing means for concentrating the electrons supplied by said virtual cathode into a beam of predetermined cross-section, a deflecting arrangement controlled by the other of said input voltages for deflecting said electron beam in a direction cross-wise to its normal axis, anode means arranged for impingement by varying fractional cross-sectional areas of said beam in accordance with its excursions from said normal axis, an output circuit connected to said anode means, and means in said output circuit for utilizing a component of the output current being a function of the product of said input voltages.

10. A system for mutually intermodulating a pair of electrical energies of different frequency comprising an electron discharge tube provided with means for producing an electron discharge stream having a first substantially diffuse portion in series with a concentrated portion forming a beam of predetermined cross-section, said means comprising means for producing a virtual cathode between said diffuse and concentrated discharge portions, means for controlling the intensity of said diffuse discharge portion in accordance with one of said energies, anode means arranged for impingement by said electron beam, further means for deflecting said beam in accordance with the other of said energies, whereby varying fractional cross-sectional areas of said beam are impinged upon said anode means, an output circuit connected to said anode means, and load impedance means in said output circuit adapted to develop output voltage having a frequency equal to the difference between the frequency of said first and second energies.

11. A system for combining a pair of electrical energies of like frequency and varying phase relation comprising an electron discharge tube provided with means for producing an electron discharge stream having a first substantially diffuse portion in series with a concentrated portion forming a beam of predetermined cross-section, means to form a virtual cathode between said diffuse and concentrated discharge portions, means for controlling the intensity of said diffuse discharge portion in accordance with one of said energies, anode means arranged for impingement by said electron beam, further means for deflecting said beam in accordance with the other of said energies, an output circuit connected to said anode means, and impedance means in said output circuit adapted to develop output voltage varying in amplitude proportionally to the phase relation between said electrical energies.

12. A phase translating device comprising an electron discharge tube provided with a cathode, a control grid, and a perforate anode, means including limiting means to excite said grid by a first alternating current potential to produce successive substantially square-shaped discharge

pulses during the positive half cycles of said potential, means to form a virtual cathode adjacent to said anode means for concentrating the electrons supplied by said virtual cathode into a beam of predetermined cross-section, a further anode arranged for impingement by said electron beam, a deflecting arrangement excited by a second alternating current potential to deflect said beam cross-wise to its normal axis, whereby varying fractional cross-sectional areas of said beam are impinged upon said anode in proportion to its excursion from said zero axis, an output circuit connected to said second anode, and means in said output circuit for utilizing a current component varying in amplitude proportionately to the phase relation between said first and second alternating current potentials.

13. A phase translating device comprising an electron discharge tube provided with a cathode, a control grid and a first perforate anode, means including a limiting impedance in the grid circuit to excite said grid by a first alternating current potential to produce successive square shaped discharge pulses during the positive half cycles of said potential, means to form a virtual cathode adjacent to said anode means for concentrating the electrons supplied by said virtual cathode into a beam of predetermined cross-section, a second anode arranged for impingement by said beam, a deflecting arrangement excited by a second alternating current potential to deflect said beam in a direction cross-wise to its normal axis such that substantially the full cross-sectional area of the beam is impinged upon said second anode by a predetermined fraction of the peak amplitude of one half cycle of the deflecting voltage, an output circuit connected to said second anode, and means in said output circuit for utilizing an output current component having an amplitude varying proportionately to the phase relation between said first and second alternating current potentials.

14. An electronic mixer tube comprising a cathode, a first perforate anode in cooperative

relation to said cathode to produce a first substantially diffuse electron discharge, a space charge control grid for controlling the intensity of said discharge, further means to produce a virtual cathode on the side of said anode away from said cathode, focussing means arranged in cooperative relation to said virtual cathode for producing a concentrated electron beam, means for deflecting said beam cross-wise to its normal axis, and a second anode arranged for impingement by varying fractional cross-sectional areas of said electron beam.

15. An electronic mixer tube comprising a cathode, a first perforate anode in cooperative relation to said cathode to produce a first substantially diffuse electron discharge, a space charge control grid for controlling the intensity of said electron discharge, a decelerating grid located at the side of said anode away from said cathode, a second anode spaced from said decelerating grid, electron beam generating means between said decelerating grid and second anode, and a deflecting arrangement to deflect the electron beam to cause varying fractional cross-sectional areas thereof to be impinged upon said second anode.

16. A modulating circuit comprising an electron discharge tube provided with means for producing a pair of substantially diffuse and concentrated electron discharge paths in series, said means including means to form a virtual cathode between said diffuse and concentrated discharge paths, means for subjecting said diffuse discharge path to intensity control in accordance with a first alternating current wave, further means for subjecting said concentrated discharge path to deflection control in accordance with a second alternating current wave, a common output circuit for said discharge paths, and load means in said output circuit to develop energy being a function of the product of said first and second alternating current waves.

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