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HIGH-FREQUENCY MODULATING SYSTEM

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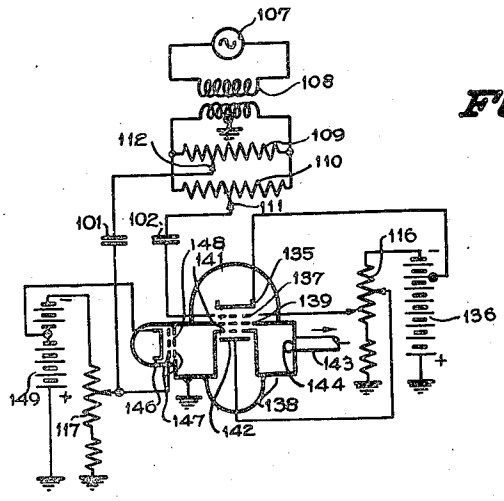


Fig. 1

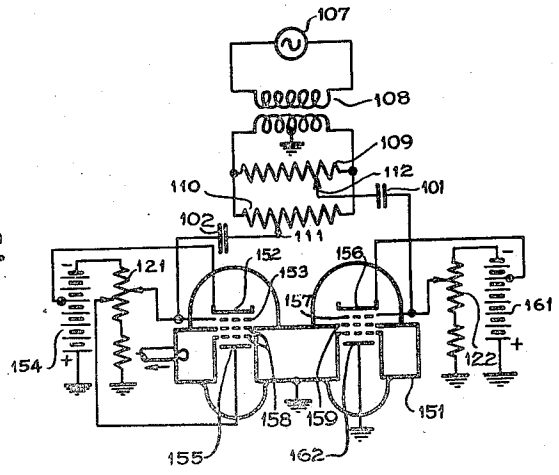


Fig. 2

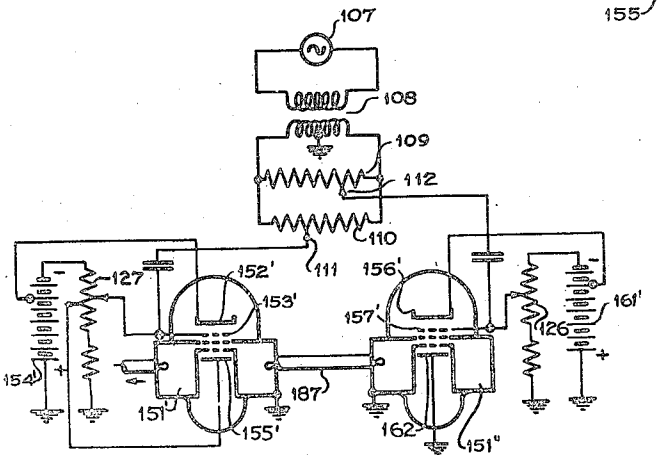


Fig. 3

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HIGH-FREQUENCY MODULATING SYSTEM

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18 Claims. (Cl. 332—17)

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This invention relates, generally, to the control of ultra high frequency electron beam velocity modulation tubes of the type disclosed in Fig. 2 of our U. S. Patent No. 2,250,511, entitled "Oscillator stabilization system," issued July 29, 1941, and, more specifically, to novel modulation means by which pure amplitude or frequency modulation can be obtained using such velocity modulation tubes.

The present application is a division of our copending application Serial No. 470,678 for High frequency modulating system, filed December 30, 1942, which itself is a continuation-in-part of our copending application Serial No. 420,770, now Patent No. 2,439,387, entitled "Electronic tuning control," filed November 28, 1941.

As is shown in our U. S. Patent No. 2,281,935, entitled "Modulation system," issued May 5, 1942, plural-resonator electron beam velocity modulation tubes may have their carrier outputs modulated by signal frequencies. The most generally employed methods of modulation have been either to insert the signal voltage in series with the beam acceleration voltage or to supply the signal voltage to a fine wire mesh control grid interposed between the cathode and the entrance grid of the first resonator of the tube. If the action takes place in an oscillator tube, frequency as well as amplitude modulation will result.

One cause of frequency modulation depends on the well known fact that a space filled with electrons has a dielectric constant which differs from the dielectric constant of free space. A variation of the electron beam current by a signal voltage on the control grid alters the dielectric constant of the resonators through which the beam passes, thus changing the effective tuning capacity and introducing a frequency change. A second source of frequency modulation lies in the change of phase between the driving voltage and the feedback voltage when the beam velocity is altered by a signal voltage in series with the beam acceleration voltage. The condition that oscillation occurs when the phase angle around the complete regenerative circuit is equal to some integral number times 2π radians indicates that any change in the transit time in the bunching space due to changes in acceleration voltage must be accompanied by a change in the phase angle between "buncher" and "catcher" resonators. This implies a frequency change accompanying the change in acceleration voltage. It is to be understood that frequency modulation will not occur in a modulated amplifier which is isolated from the oscillator by a buffer resonator. This

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procedure is, however, often undesirable since three more resonators are added which complicate the apparatus and greatly increase the tuning problem.

On the other hand, under some circumstances, due to the sharpness of the resonance curves of the resonators themselves, it is difficult to produce a pure frequency modulated carrier without simultaneous amplitude modulation.

It has been disclosed in above-mentioned Patent No. 2,281,935 that pure amplitude modulation or pure frequency modulation may be obtained by using combinations of acceleration voltage modulation and beam current modulation of the proper amount and in the correct phase relationship. This has the disadvantage, however, that acceleration voltage modulation requires a large signal amplitude and abstracts power from the signal source.

In "reflex" type velocity modulation tubes, such as shown in Fig. 2 of our Patent No. 2,250,511, similar modulation can be effected by variation of the beam-accelerating voltage or of the control grid voltage by the modulating signal.

According to the present invention, an improved system and method is provided for obtaining, as desired, either amplitude or frequency modulation in ultra high frequency oscillators of the reflex velocity modulating type without the simultaneous occurrence of the undesired form of modulation. Also according to the present invention a novel method is provided for obtaining predetermined relative amounts of amplitude and frequency modulation in ultra-high-frequency oscillators.

Another object of the present invention is to provide means for obtaining pure amplitude or pure frequency modulation with moderate amplitude modulating signals and negligible signal power consumption by impressing the signal upon the control grid of a reflex velocity modulation device and simultaneously upon a control grid coacting with an independent electron stream coacting with the electromagnetic field of said device.

Still another object is to modify the modulation characteristics of a reflex velocity modulation tube by altering the dielectric constant within the resonator of the device with an auxiliary electron beam.

A further object of the present invention lies in the provision, in an ultra frequency reflex velocity modulation tube, of an auxiliary electron beam adapted to maintain the average electron density within a common resonator substantially

constant when the average electron density of the main electron beam is modulated by a signal voltage.

Another object is to provide means and methods in an ultra high frequency tube of the character described for selectively obtaining either pure amplitude modulation or pure frequency modulation by a simple operational adjustment.

Yet a further object is to provide, in an electron beam velocity modulating oscillator having a cavity resonator, means for controlling the average electron density within the resonator in accordance with a signal wave either to produce or to compensate for changes in the resonant frequency of the oscillator without imparting energy to the high frequency field therein comprising means for projecting an electron beam through the high frequency field of the resonator, and grid means for controlling the beam current, the beam being so directed as to be collected by the side of the resonator or other collector means without providing feedback coupling with the field.

Other objects and advantages will become apparent from the specification, taken in connection with the accompanying drawings wherein the invention is embodied in concrete form.

In the drawings,

Fig. 1 is a schematic wiring diagram of one form of our invention.

Figs. 2 and 3 are schematic wiring diagrams of modifications of the invention.

Similar characters of reference are used in all of the above figures to indicate corresponding parts.

It has been demonstrated mathematically and verified experimentally that the presence of free electrons within an electric field may either increase or decrease the dielectric constant of the space containing these charges from the unity value of a pure vacuum. For example, it is observed in the study of the ionosphere that the dielectric constant may be reduced to zero and even reversed in sign by the action of the electrons. The effect is mathematically very complex but it is a function, among others, of the electron density, the frequency of the electric field, and the transit time of the electrons passing through the field. In general, it may be said that if the electrons are projected in a low velocity beam and remain within the electric field for a duration long compared to a cycle of the field frequency, the dielectric constant is decreased by their presence. Contrarily, electrons projected through the electric field at a high velocity in a time short compared to a cycle of the field frequency cause an increase in the dielectric constant. The ionosphere exhibits the former effect while most electron velocity modulating devices exhibit the latter effect since electrons remain in the impressed electric fields for long and short durations, respectively. In the present invention both modes of operation are contemplated, and therefore, operating conditions stated for explanatory purposes are not to be considered in any way to limit the device to the exclusive employment of either high or low velocity electron beams.

Referring now to Fig. 1, there is seen diagrammatically a type of reflex electron beam velocity modulating tube of the type shown in U. S. Patent No. 2,250,511 but having a transverse electron control beam similar to that disclosed in Fig. 3 of the above-mentioned copending application Serial No. 420,770. The device comprises an electron emissive cathode 135 from which an electron beam is accelerated by the potential from a battery 136 through a mesh control grid 137 and thence through a resonator 138 having entrance and exit grids 139 and 141, respectively. Behind exit grid 141 is mounted a reflector plate 142 supplied with a voltage from a tap on the battery 136. The electron beam is reflected back into the resonator 138 where it maintains an ultra high frequency field in the well known manner. A coaxial line 143 attached to a coupling loop 144 is adapted to remove energy from the resonator 138.

Attached to the side of resonator 138 is a means for producing an electron beam transverse to the electric field of the resonator. A cathode 146 of this device produces an electron beam which is accelerated through a mesh control grid 147 and through a grid 148 in the side wall of resonator 138 by a voltage supplied by a battery 149, so that the beam passes substantially at right angles to the electron beam from cathode 135 and between resonator grids 139, 141, preferably without impinging on these latter grids or the resonator walls supporting these grids, being therefore collected on the opposite outer resonator wall. Loop 144 and line 143 are shown in the plane of the paper for convenience in drawing, but would preferably be located so that the beam from cathode 146 would not strike them. The modulation control grids 137 and 147 are connected to the taps 111 and 112, respectively, of the potentiometers 110 and 109, respectively, both fed from the modulating signal source 107 through transformer 108.

In operation, the beam from cathode 146 contributes no energy to aid in maintaining the oscillating electromagnetic field within the resonator; in fact, it unavoidably extracts a small amount of energy. If the beam current intensity from cathode 135 is increased, there results an increase in the amplitude of oscillation of the electromagnetic field and a decrease in its frequency as a consequence of the tuning effect on the resonator. An increase in the beam current from cathode 146, however, produces a decrease in output, due to its effect in loading the resonator, as well as a decrease or increase in output frequency dependent upon whether the control beam has a positive or negative effect on the dielectric constant of the resonator. Predetermined amounts of amplitude and frequency modulation may be obtained, therefore, by the amplitude and phase adjustment of the signal voltages on the control grids 137 and 147.

Fig. 2 illustrates an alternate form of the present invention wherein a reflex type of ultra high frequency oscillator has an auxiliary electron beam projected at preferably a low velocity parallel to the exciting electron beam. A resonator 151 of the device of Fig. 2 has a cross-section similar to that shown in Fig. 4 of parent application No. 470,678. Cathode 152 provides an electron beam whose intensity is controlled by a grid 153 and which is accelerated by a battery 154 through entrance and exit grids 158 in the resonator 151. A reflector electrode or plate 155 maintained at an appropriate voltage by a tap on voltage divider 121 connected across the battery 154 returns the beam to the resonator 151 which is excited thereby in the usual manner.

Cathode 156 emits electrons which are projected by the acceleration voltage of a battery 161 past control grid 157, and through a second pair of entrance and exit grids 159 in the resonator

151. The beam from cathode 156 is dissipated by a collector electrode or reflector plate 162 connected to a source of suitable potential and therefore supplies no energy to the ultra high frequency field. Grids 153 and 157 are coupled to the signal source 107 by means of taps 111 and 112, respectively, of the potentiometers 110 and 109, respectively, through blocking condensers 101 and 102. The modulation charactertistics of this device may be altered in a similar manner to the devices previously discussed.

Fig. 3 illustrates a modification of the device shown in Fig. 2 wherein the resonator 151 is separated into a driving resonator 151' and a tuning resonator 151'' coupled by a coaxial line 187. Resonator 151'', which may be similar to the resonators discussed with reference to Fig. 11, of patent application No. 470,678, couples an impedance to resonator 151' in a manner analogous to simple coupled circuits. The operation of the device shown in Fig. 3 is similar to that of Fig. 2 and consequently needs no special explanation.

It appears obvious that the teachings of the present invention may be extended to other types of electron beam velocity modulation devices that have radial shooting exciting beams, annular resonators, and similar structural modifications. The usual tuning arrangements may be employed with the illustrated embodiments of the present invention. Great latitude may be exercised in design of resonators, use of smoothing grids, employment of collector electrodes for mixer operation, and in similar engineering decisions.

As many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A method of simultaneously producing desired relative amounts of amplitude and frequency modulation ranging from substantially pure amplitude modulation to substantially pure frequency modulation, comprising the steps of projecting a plurality of electron beams through an electromagnetic field, reflecting one of said beams to re-pass through said field to sustain oscillations thereof, collecting the other of said beams after the first passage thereof through said field, and varying the intensities of said beams in accordance with the same signal waves with an amplitude and phase relationship dependent upon the desired relative amounts of amplitude and frequency modulation of said field.

2. A method of simultaneously producing desired relative amounts of amplitude and frequency modulation ranging from pure amplitude modulation to substantially pure frequency modulation, comprising the steps of projecting an electron beam through an ultra high frequency electromagnetic field, reversing and re-projecting said beam through said field to sustain oscillation thereof, projecting an auxiliary electron beam solely for tuning purposes perpendicularly through at least a portion of said field, modulating the intensities of said electron beams in accordance with signal waves having a predetermined amplitude and phase relationship, and extracting energy from said field having the desired relative amounts of amplitude and frequency modulation of said field.

3. A method of simultaneously producing desired relative amounts of amplitude and frequency modulation ranging from substantially pure amplitude modulation to substantially pure frequency modulation, comprising the steps of maintaining an electromagnetic field in oscillation at a predetermined frequency by double traverse of an electron beam therethrough, producing an auxiliary unidirectional electron beam coupled to said field, and controlling both said electron beams in accordance with the same signal waves with amplitude and phase relationships dependent upon the desired relative amounts of amplitude and frequency modulation of said field.

4. An electron beam velocity-modulating device adapted to produce simultaneously desired relative amounts of amplitude and frequency modulation, comprising cavity resonator means, means for projecting an electron beam through said resonator means, means for reversing and re-projecting said beam through said resonator means to excite electromagnetic oscillations at a predetermined frequency therewithin, means for projecting an auxiliary electron beam through said resonator means to coact with said oscillations without imparting energy thereto, means for collecting said auxiliary beam after its passage through said resonator means, and means for varying the intensities of said beams in accordance with a signal wave, said last-mentioned means being adapted to control the relative amplitudes and phases of said electron beam intensities dependent upon the desired relative amounts of amplitude and frequency modulation.

5. Means for simultaneously producing desired relative amounts of amplitude and frequency modulation ranging from substantially pure amplitude modulation to substantially pure frequency modulation, comprising resonator means, means for projecting an electron beam through said resonator means, means for reversing and re-projecting said beam through said resonator means to excite an electromagnetic field therewithin, means for projecting an auxiliary electron beam through at least a portion of said field without imparting energy thereto, and means for simultaneously varying the intensities of said electron beams in accordance with a signal wave and with an amplitude and phase relationship dependent upon the desired relative amounts of amplitude and frequency modulation.

6. In an electron beam velocity-modulating device having means for producing an electron beam and a single resonator adapted both to velocity-modulate said electron beam and to be electromagnetically excited by the same beam upon subsequent reflection of the latter in density-modulated form through said resonator, the combination comprising means for varying the intensity of said exciting electron beam in accordance with a modulating signal, means for projecting an auxiliary electron beam through said resonator, means for collecting said auxiliary beam after initial passage thereof through said resonator, and means for varying the intensity of said auxiliary electron beam in accordance with said modulating signal to maintain the average electron density in said resonator substantially constant.

7. Modulation control apparatus comprising a hollow cavity resonator, means for projecting an electron beam therethrough, means including a reflector electrode adjacent said resonator for reversing said beam to reenter said resonator and to produce an electromagnetic field therewithin,

a second resonator coupled to said first resonator, means for projecting an auxiliary electron beam through said second resonator, means for collecting said auxiliary beam after its initial passage through said second resonator, and means for controlling said auxiliary beam in accordance with a modulation signal to produce modulation of said field.

8. Modulation control apparatus comprising means for producing an electromagnetic field including a hollow cavity resonator, means for projecting an electron stream therethrough, and means for reversing said stream to reenter said resonator; means for producing a unidirectionally flowing auxiliary electron stream coupled to said field, and means for controlling both of said streams in accordance with a modulation signal to produce modulation of said field.

9. Modulation control apparatus comprising means for producing an electromagnetic field including a hollow cavity resonator, means for projecting an electron stream therethrough, and means for reversing said stream to reenter said resonator; means for producing a unidirectionally flowing auxiliary electron stream coupled to said field, means for controlling said first electron stream in accordance with a modulation signal to produce modulation of said field, and means for modifying said modulation, comprising means for controlling said auxiliary electron stream by said same modulation signal.

10. High frequency apparatus comprising a hollow cavity resonator having electron-permeable walls, means for projecting a beam of electrons through said resonator by way of said walls, means for reversing said electrons to cause them to reenter said resonator to sustain oscillations therein, means for modulating said oscillations comprising means for controlling said electron stream by a modulation signal, and means for controlling the modulation of said output comprising a second cavity resonator coupled to said first resonator, means for passing a stream of electrons through said second resonator, and means for controlling said second stream by said signal.

11. Modulation control apparatus for simultaneously producing predetermined amounts of amplitude and frequency modulation, comprising first and second discharge devices each having an electron gun, a modulation control grid, a resonator, and a electrode, located in axial consecution, said electrode of one of said devices being connected to a source of ground potential, a modulator having a single signal source and connected to said modulation control grids of said devices, an energy coupler directly connecting the resonators of said devices, and means for extracting energy from one of said resonators.

12. Apparatus for simultaneously producing predetermined relative amounts of amplitude and frequency modulation ranging from substantially pure amplitude modulation to substantially pure frequency modulation, comprising a first velocity modulation discharge device having an electron gun, modulation control grid, resonator, and a reflector, all located in axial consecution, said modulation control grid being connected to a source of predetermined direct potential, a second discharge device having an electron gun, a modulation control grid, and an electrode, all located in axial consecution, said electrode being connected to a source of predetermined direct potential substantially higher than said first-mentioned direct potential, a common modulation signal source connected to said modulation control grids and said devices, and an energy coupler connecting the resonators of said devices.

13. Modulation control apparatus comprising a source of first and second beams of electrons, an electron resonant chamber means having a predetermined resonant frequency, a modulator connected to receive both the first and second beams of electrons and having a single source of modulation signal, means for defining a first beam path through said resonant chamber means for receiving said first beam of electrons, said first beam path having a transit time length substantially long compared to the duration of a cycle of said predetermined resonant frequency, further means for defining a second beam path through said resonant chamber means for receiving said second beam of electrons, said second beam path having a transit time length substantially short compared to said transit time length of said first beam path, and means for extracting energy from said resonant chamber means, said energy having predetermined relative amounts of amplitude and frequency modulation.

14. Modulation control apparatus, comprising a first and second source of electron beams, a first and second modulation means connected to receive said first and second electron beams respectively, electromagnetic resonant chamber means having a predetermined resonant frequency and further having two reentrant portions each defining an electron permeable gap, means for directing said first and second beams of electrons through said electron permeable gaps, a first and second reflector plate connected in axial alignment with the paths of said first and second beams of electrons respectively, one of said reflector plates being connected to a substantially higher potential than the other said reflector plate, and energy extracting means connected to said resonator chamber means.

15. A method of simultaneously producing desired relative amounts of amplitude and frequency modulation, comprising the steps of maintaining an electromagnetic field in oscillation at a predetermined frequency by passing an electron beam therethrough in a time duration substantially short compared with the period of said predetermined frequency, and directing a second beam through said field in a time duration substantially long compared with said predetermined frequency, one of said beams being directed in a double traverse of said electromagnetic field and the other of said beams in a single traverse of said field.

16. A method of simultaneously producing desired relative amounts of amplitude and frequency modulation ranging from substantially pure amplitude modulation to substantially pure frequency modulation, comprising the steps of maintaining an electric field in oscillation at predetermined frequency by double traverse of a first electron beam therethrough in a time duration substantially short compared with the period of said predetermined frequency, and directing a second auxiliary beam through said field in a time duration substantially long compared with said predetermined frequency.

17. A method of simultaneously producing desired relative amounts of amplitude and frequency modulation ranging from substantially pure amplitude modulation to substantially pure frequency modulation, comprising the steps of maintaining an electric field in oscillation at predetermined frequency by double traverse of a

first electron beam therethrough in a time duration substantially short compared with the period of said predetermined frequency, directing a second auxiliary beam through said field in a time duration substantially long compared with said predetermined frequency, and modulating both said beams with the same modulating signal.

18. A method of eliminating unwanted frequency modulation in a velocity modulation discharge device having a cathode, a modulating grid, a resonator, and a reflector plate, comprising the steps of directing an auxiliary beam of electrons through a portion of the electromagnetic field of said resonator in a time duration substantially long compared with the frequency of said resonator, and modulating said auxiliary beam with the same modulation signal as said modulating grid.

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