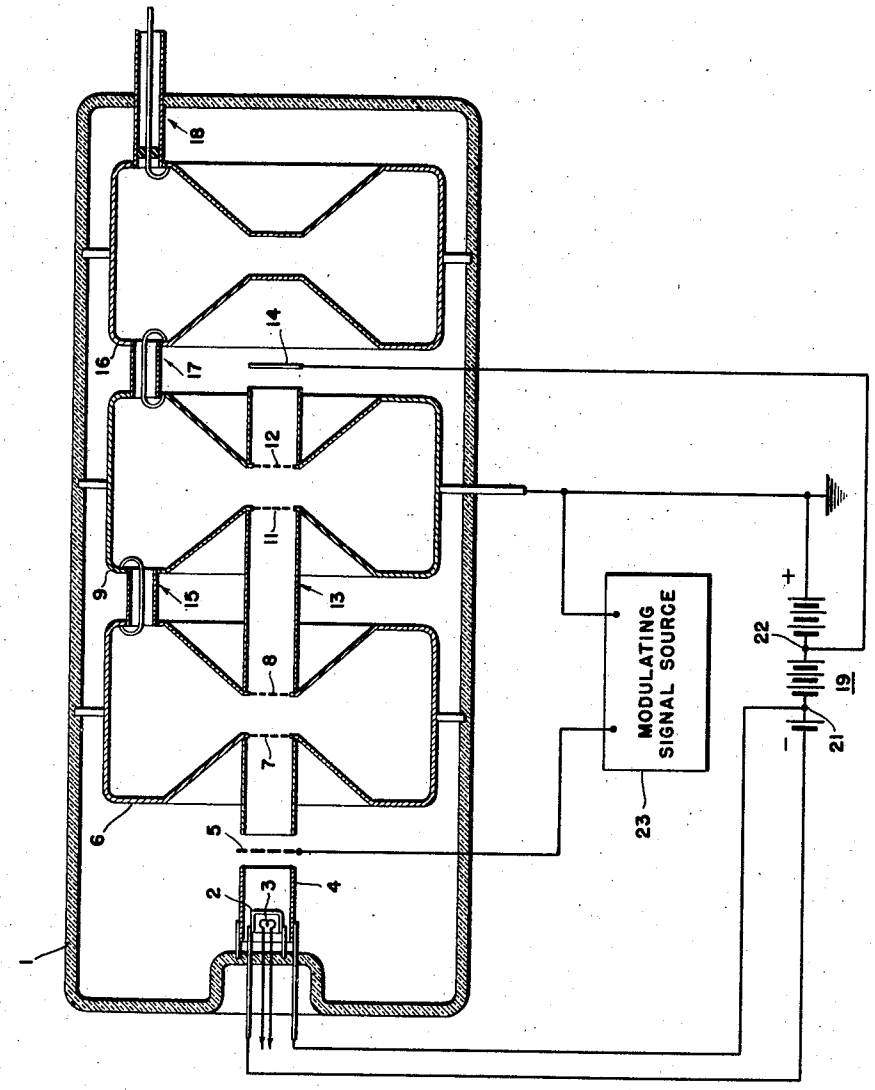
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HIGH FREQUENCY APPARATUS

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HIGH-FREQUENCY APPARATUS

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This invention relates to modulating systems, and particularly to systems of this character which include apparatus employing the principles of velocity modulation of an electron beam.

Velocity modulation apparatus often is used at relatively high operating frequencies where utilization may be made of electron transit time. In such apparatus, an electron beam is influenced by an alternating field produced by a resonant device in such a manner that it is velocity modulated; that is, some electrons are accelerated and others are decelerated. The velocity modulated electron beam is permitted to traverse a drift space. By the time the electrons forming the beam reach the end of the drift space, the accelerated electrons have overtaken the decelerated electrons. By this means there are produced electron bunches or groups. In this form the electron beam is said to have a charge density modulation. The charge density modulated beam then is passed through the alternating field produced by another resonant device. The phase relation of this field with respect to the charge density modulated electron beam is of such a character that the electrons forming the bunches are decelerated and thereby give up energy to the resonant circuit. Thus, this resonant device is excited by the charge density modulated electron beam. Energy is coupled from the extracting resonant device into the desired utilization circuit. In some cases a portion of the energy developed by the extracting resonant device is coupled back to the velocity modulating resonant device for the excitation thereof. By this means the apparatus is conditioned to operate so as to produce self-sustained oscillatory energy.

Apparatus of this character is capable of generating a relatively high frequency carrier wave. Where it is desired to modulate such a carrier wave in amplitude in accordance with an intelligence signal, a conventional arrangement is to impress the modulating signal upon a control grid by means of which the intensity of the electron beam may be varied before it is subjected to the influence of the velocity modulating field. In effecting the intensity variation of the electron beam in this manner the potential of the control grid with respect to the electron source is varied in accordance with the modulating signal. By reason of this potential variation, the accelerating action of the control grid upon the electrons forming the beam also varies correspondingly. The result is that the electrons which are permitted to pass the control grid to effect the desired amplitude modulation not only

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vary in number but also vary in velocity. Consequently, there is produced in the output circuit of such apparatus a carrier wave having the desired amplitude modulation component and also an undesired frequency modulation component resulting from the velocity variation of the electron beam produced by means of the signal controlled variations of the control grid potential.

It is an object of the present invention, therefore, to provide novel means for effecting an amplitude modulation of the energy derived from velocity modulation apparatus without concomitantly producing any appreciable frequency modulation of the energy.

In accordance with this invention there is provided frequency modulation apparatus constituting a source of high frequency energy. With respect to the means for generating and signal modulating the high frequency energy the apparatus is conventional. It comprises a means for developing an electron beam and a means for varying the intensity of the beam in accordance with intelligence signals. The intensity varying means most conveniently used has as an inherent characteristic of its intensity varying capability the propensity of effecting a slight velocity variation of the beam in accordance with the intelligence signals. Conventional means are provided for effecting a charge density modulation of the electron beam in accordance with a radio frequency. There also are included facilities for developing from the modulated electron beam, radio frequency energy having an amplitude modulation corresponding to the modulation of the electron beam. This energy has the desired amplitude modulation, but also has an undesired frequency modulation, both of which are in accordance with the intelligence signals. In conjunction with conventional apparatus of the general character described, there is provided additionally, in accordance with this invention, a means resonant substantially at the radio frequency for deriving energy from the energy developing means at the radio frequency and having a maximum of amplitude modulation and a minimum of frequency modulation in accordance with the intelligence signals. Substantial resonance at a predetermined radio frequency, as the term is used in the following description and appended claims, is intended to denote peak resonance at the radio frequency or at a frequency which is a slight deviation from the radio frequency.

For a better understanding of the invention, together with other and further objects thereof, reference is had to the following description taken

in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

In the accompanying drawing, the single figure is a diagrammatic illustration of high frequency energy generating apparatus embodying the invention in a preferred form.

Referring now to the drawing, the high frequency generating apparatus comprises a velocity modulation tube. The various electrodes of the tube are mounted within an evacuated tube envelope 1. An electron emissive cathode 2 is mounted within the tube adjacent one end thereof. A filamentary heater element 3 is located inside of the cathode so that the cathode may be heated sufficiently to effect the emission of electrons. The heater 3 may be connected as indicated to any convenient source of energy. A cylindrical focusing electrode 4 is mounted in a manner to surround the space adjacent to the cathode 2. A control grid 5 is mounted within the tube adjacent to the right hand end of the focusing electrode.

Farther to the right there is mounted within the tube a hollow resonant chamber 6 constituting one form of a velocity modulating resonant device. This chamber is provided with a centrally located aperture in alignment with the longitudinal axis of the focusing electrode 4 and also with the center of the cathode 2. This aperture is of such a character to form a gap of predetermined dimensions along the longitudinal axis of the tube. There is mounted in this aperture a pair of grids 7 and 8.

Still farther to the right there is mounted a second hollow resonant chamber 9 constituting one form of an energy extracting resonant device. This chamber may or may not be of the same shape as the chamber 6, as desired. In any case it is of a character to resonate at the same frequency at which the chamber 6 is resonant. The chamber 9 also has a centrally located aperture of such a character as to form a gap of predetermined dimensions along the longitudinal axis of the tube. A pair of grids 11 and 12 are mounted in the chamber aperture.

An electron drift tube in the form of a hollow cylinder 13 extends from the grid 8 of the velocity modulating chamber 6 to the grid 11 of the energy extracting chamber 9. To the right of the extracting chamber there is mounted an electron collecting electrode 14. A back coupling between the extracting chamber 9 and the modulating chamber 6 is provided by a concentric transmission line 15.

The apparatus also is provided with an auxiliary resonant chamber 16 constituting one form of an output resonant device. This chamber is not provided with an aperture and its operation is in no way influenced by the electrons emitted by the cathode 2. It, however, is designed to have a relatively high "Q" and is of such a character to resonate at substantially the same or, as subsequently explained, a slightly different resonant frequency of the chambers 6 and 9. It is coupled loosely, in a manner to be more fully described subsequently, by means of a concentric transmission line 17 to the energy extracting chamber 9. It also is coupled loosely by a concentric transmission line 18 to any desired utilization circuit located outside of the tube.

Operating potentials are supplied to the described apparatus from a source of unidirectional energy such as a battery 19. The negative terminal of the battery is connected to the cathode 2,

The focusing electrode 4 may be operated either at the cathode potential or at a potential slightly negative or somewhat positive with respect to the cathode. As illustrated herein, the focusing electrode is connected to an intermediate tap 21 on the battery so that it is operated at a slightly positive potential relative to the cathode. The resonant chambers 6, 9 and 16 are electrically interconnected by means of the outer conductors of the coupling transmission lines 15 and 17. These chambers are operated at the highest positive potential relative to the cathode, and consequently, are connected to the grounded positive terminal of the battery 19. The collector electrode 14 is operated at a somewhat lower positive potential by means of a connection to an intermediate tap 22 on the battery 19. A source of modulating signal 23 is connected between ground and the intensity control grid 5.

Referring now to the operation of the apparatus, a brief consideration will be given to the functioning thereof to develop radio frequency energy. The electrons emitted by the cathode 2 are focused into a beam of predetermined cross-sectional area by means of the electrode 4. The intensity modulation of the beam by means of the grid 5 will be neglected for the moment. The electron beam which as formed has a uniform velocity, in passing through the grids 7 and 8, enters and leaves the field produced between the grids. By reason of the alternating character of this field the velocity of different portions of the beam is varied. Such a modification of the electron beam velocity is known as velocity modulation of the beam. In other words, some of the electrons are accelerated and some others are decelerated.

After leaving the grid 8, this velocity modulated electron beam traverses the space within the drift tube 13. During its travel through the drift tube the beam is uninfluenced. As a consequence, when the grid 11 is reached by the electron beam it no longer is continuous. By this time the accelerated electrons have overtaken the decelerated electrons and, as a consequence, there are produced electron groups or bunches. An electron beam of this character is said to have a charge density modulation. The field produced between the grids 11 and 12 also is of an alternating character. The phase of this field with respect to the charge density modulated electron beam is such that the grouped electrons are decelerated by their passage into and out of the field formed between the grids 11 and 12. In this manner energy is extracted from the electron beam to excite the resonant chamber 9. The decelerated electrons finally are collected by the electrode 14.

Where it is desired to excite the velocity modulating chamber 6 from the energy extracting chamber 9, a small portion of the electromagnetic energy developed in the extracting chamber is coupled back into the modulating chamber by means of the transmission line 15. Apparatus so arranged is self-oscillatory. However, it is contemplated to be within the scope of this invention that the modulating chamber be excited by externally derived radio frequency energy.

The transmission line 17 also is instrumental in coupling some of the energy developed in the extracting chamber 9 into the auxiliary output chamber 16. The loops formed adjacent the ends of the central conductor of the line 17 are positioned in the respective chambers 9 and 16 at points of relatively low field strength for a pur-

pose to be described more fully subsequently. In this manner a portion of the energy developed in the extracting chamber 9 is employed to excite the output chamber 16. The energy developed in this latter chamber is coupled into a utilization circuit by the transmission line 18.

In order to effect an amplitude modulation of the carrier frequency energy developed by apparatus of this character, the intensity of the electron beam is varied in accordance with an intelligence signal before it is subjected to the influence of the modulating chamber 6. The modulating signal voltages impressed upon the control grid 5 vary the intensity of the electron beam in a well known manner. Under the control of a strong modulating signal a high intensity of the beam is produced. Consequently, the electron density of the bunched electrons resulting from the strong signal modulation is high. These bunched electrons thus are able to give up a relatively large amount of energy to the extracting chamber 9. Conversely, under the control of a relatively weak modulating signal there is produced an electron beam of low intensity. As a result, the electron density of the bunched electrons traversing the field between the grids 11 and 12 is low. These electron groups therefore are able to give up only a small amount of energy to the extracting chamber 9. The strength of the electromagnetic field produced within the extracting chamber is directly proportional to the amount of energy extracted from the charge density modulated electron beam. Consequently, the amplitude of the energy which it is possible to derive from the extracting chamber varies directly with the strength of the field within the chamber and thus with the strength of the modulating signal. Thus, there is produced the desired result of deriving from apparatus of this character energy at a radio frequency which is modulated in amplitude in accordance with an intelligence signal.

The intensity variation of the electron beam by means of the control grid 5 is effected by varying the voltage of this grid with respect to the cathode 2. The acceleration given to the electrons emitted by the cathode is determined in part by the voltage difference between the control grid and the cathode.

Consequently, when this voltage is varied under the control of the modulating signals the acceleration of the emitted electrons also varies, with the result that the intensity modulated electron beam also is velocity modulated to a slight degree. This preliminary velocity modulation is in accordance with and at the frequency of the modulating signal as distinguished from the velocity modulation of the beam effected by the chamber 6 which is in accordance with and at the desired radio carrier frequency. As a result, the electromagnetic energy developed in the extracting chamber 9 at the desired radio frequency has both an amplitude modulation component and a velocity modulation component in accordance with the intelligence signal.

In order to substantially eliminate the frequency modulation component from the radio frequency energy derived from the extracting chamber 9, there is provided a loose coupling including the output resonant chamber 16 between the extracting chamber of the velocity modulation device and the utilization circuit. The loose coupling is provided by the disposition of the loops formed in the central conductor of the transmission line 17 within the chambers 9 and 16. As described, the positions of these loops are at points within the respective chambers where the field strength is low. In addition, the size of each of these loops is relatively small. As a consequence, only a relatively small portion of the energy developed in the extracting chamber 9 is coupled into the output chamber 16.

Also characteristically of loosely coupled circuits of any type, the energy transferred from one chamber to the other is predominantly at the frequency at which the chambers are resonant. Therefore, only a narrow band of frequencies centering about the radio frequency at which the chambers are resonant is coupled into the output chamber 16. By suitable design this band may be made narrow enough so that, for all practical purposes, energy only at the resonant radio frequency is developed in the output chamber 16. In this manner the frequency modulation component of the energy developed in the extracting chamber 9 may be substantially eliminated. The energy which is derived from the output chamber by means of the transmission line 18, therefore, contains only the amplitude modulation component.

In order for apparatus of this character to function efficiently, it is preferable that the output chamber 16 have a high "Q." In other words, the efficiency of this circuit component should be as high as possible in order that the losses therein may be minimized. Such a characteristic of this chamber is desirable for the reason that, in order to eliminate the frequency modulation component from the energy derived from the extracting chamber 9 by means of the transmission line coupling provided, it is possible to transfer only a relatively small amount of energy from the extracting chamber to the output chamber. The output chamber 16 may be made to have a high "Q" by reason of the fact that apertures therein are not required. The apertures of the chambers 6 and 9 in the path of the electron beam prevent these chambers from having a "Q" as high as that of the chamber 16 and, as a consequence, permit the chambers 6 and 9 to respond to a band of frequencies and, therefore, develop the undesired frequency modulation component.

It should be noted that the invention is not limited to embodiments thereof employing electromagnetic coupling of a loose character between the energy extracting resonant circuit and the output resonant circuit. Any type of loose coupling between these two circuits may be used with equal facility without departing from the scope or spirit of the invention. For example, the two chambers may be effectively coupled by means of their electric fields simply by suitably joining the two chambers by a small aperture formed in a common wall between the chambers and located properly at points of relatively low field strength.

Apparatus of the character described also is susceptible of use in a manner whereby the frequency modulation component is substantially suppressed as described, and also the amplitude modulation component is increased as a concomitant result. In such a case the resonant output chamber 16 is tuned for peak resonance at a frequency which is slightly different from the radio frequency of the energy which is developed by the device. With respect to the characteristic response curve of a resonant device of this character, the desired radio frequency of the developed energy will be located on the steep slope of the resonance curve for the chamber 16. This cham-

ber then will function in a well known manner to develop the amplitude modulation component of the radio frequency energy. At the same time, the frequency modulation component of the energy coupled into this chamber from the energy extracting chamber 9 will cause the output chamber to respond in different amplitudes to the various frequency deviations from the predetermined radio frequency of the energy developed in the energy extracting chamber. It, therefore, is seen that by this means the undesired frequency modulation component may be converted into an additional amplitude modulation component. Thus, the resultant signal energy derived from the output chamber 16, by means of the transmission line 18, has a substantial amplitude modulation component and substantially no frequency modulation component.

While there has been described what, at present, are considered the preferred embodiments of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and therefore, it is aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. In a modulating system, means for generating an electron beam, a source of intelligence signals, means in the path of said beam and controlled by said intelligence signal source for varying the intensity of said beam in accordance with said intelligence signals, said intensity varying means having as an inherent characteristic of its intensity varying capability the propensity of effecting a slight velocity variation of said beam in accordance with said intelligence signals, means including a resonant chamber for effecting a velocity modulation of said beam, means including an electron drift tube for effecting a charge density modulation of said velocity modulated beam, means including a resonant chamber for extracting energy from said charge density modulated beam, an auxiliary resonant chamber, all of said chambers being resonant at a predetermined radio frequency, means for exciting said velocity modulating resonant chamber at said radio frequency, means controlled by said extracted energy for exciting said auxiliary chamber substantially only at said radio frequency, and means coupled to said auxiliary resonant chamber for deriving energy therefrom at said radio frequency and modulated in amplitude only in accordance with said intelligence signals.

2. In a modulating system, means for generating an electron beam, a source of intelligence signals, means including a control grid in the path of said beam and controlled by said intelligence signal source for varying the intensity of said beam in accordance with said intelligence signals, said control grid having as an inherent characteristic of its intensity varying capability

the propensity of effecting a slight velocity variation of said beam in accordance with said intelligence signals, a velocity modulating resonant chamber in the path of said beam, an energy extracting resonant chamber in the path of said beam, an electron drift tube interconnecting said modulating and extracting resonant chambers, an auxiliary resonant chamber, all of said chambers being resonant at a predetermined radio frequency, means for exciting said velocity modulating resonant chamber at said radio frequency, means loosely coupling said extracting and said auxiliary resonant chambers for exciting said auxiliary chamber substantially only at said radio frequency, and means loosely coupled to said auxiliary resonant chamber for deriving energy therefrom at said radio frequency and modulated in amplitude only in accordance with said intelligence signals.

3. In a modulating system, means for generating an electron beam, a source of intelligence signals, means including a control grid in the path of said beam and controlled by said intelligence signal source for varying the intensity of said beam in accordance with said intelligence signals, said control grid having as an inherent characteristic of its intensity varying capability the propensity of effecting a slight velocity variation of said beam in accordance with said intelligence signals, a velocity modulating resonant chamber having an aperture in the path of said beam, an energy extracting resonant chamber having an aperture in the path of said beam, an electron drift tube interconnecting the apertures of said resonant chamber, an unapertured resonant chamber, all of said chambers being resonant at a predetermined radio frequency, means for exciting said velocity modulating resonant chamber at said radio frequency, means including a coaxial transmission line loosely coupling said extracting and said unapertured resonant chambers for exciting said unapertured chamber substantially only at said radio frequency, and means loosely coupled to said unapertured resonant chamber for deriving energy therefrom at said radio frequency and modulated in amplitude only in accordance with said intelligence signals.

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