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OSCILLATORS

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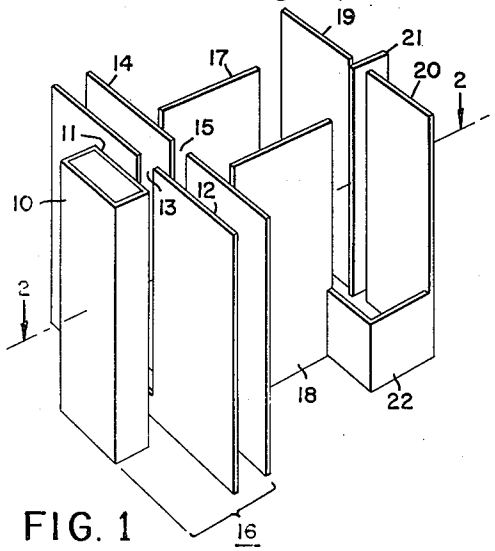


FIG. 1

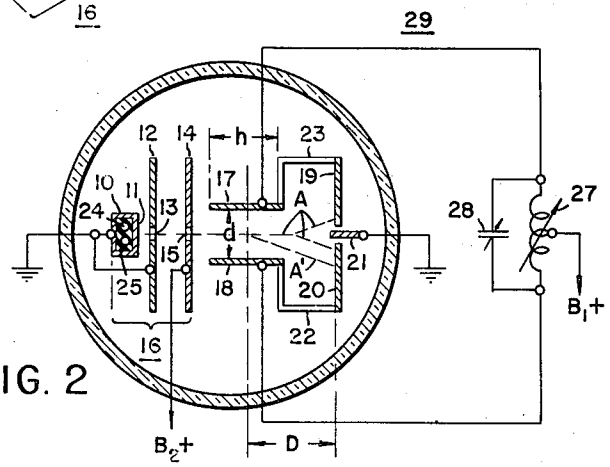


FIG. 2

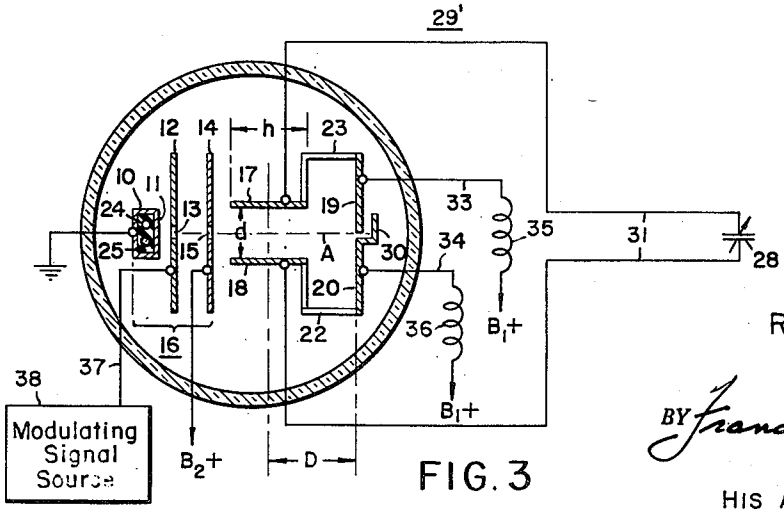


FIG. 3

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OSCILLATORS

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This invention pertains to new and improved oscillators suitable for use at relatively high frequencies and more particularly to oscillators employing beam-deflection tubes and to the structure of beam-deflection tubes adapted for use in high-frequency oscillators.

Relatively recent advances in the electronics art have brought about an increased use of the higher-frequency portions of the frequency spectrum for commercial purposes, as exemplified by the very-high-frequency (V. H. F.) and ultra-high-frequency (U. H. F.) television broadcast bands and the frequency-modulation radio band. As a result, manufacturers of receivers adapted for use at these frequencies have been faced with the necessity of developing suitable stable oscillators for generating, demodulating or heterodyning signals within the same general range of frequencies. Intensity-modulation devices of the familiar grid-control type which are capable of operation as oscillators within both the V. H. F. and U. H. F. ranges have been developed; however, these tubes present several inherent difficulties, among which are the necessity for maintaining relatively exacting dimensional tolerances in the electrode structures of the tubes and the problems presented in compensating for changes in the electrical characteristics of the devices due to variations in thermal operating conditions. Velocity-modulation devices such as klystrons and magnetrons, on the other hand, appear to be too complex and expensive for most receiver applications and are not particularly satisfactory for operation in the lower or V. H. F. portion of the newly-utilized frequency ranges.

In addition to the intensity- and velocity-modulation devices noted above, high-frequency oscillators employing beam-deflection tubes have been proposed. Conventionally, a beam-deflection tube so employed comprises an electron gun for projecting a stream of electrons along a reference path, a pair of deflectors disposed on opposite sides of that path, and a pair of anodes arranged on opposite sides of the path and spaced from the deflectors. Each anode is connected to the deflector on the opposite side of the beam path from that anode, and a resonant circuit is connected across the anodes. Oscillators of this type are operable over a relatively wide range of frequencies; however, they are inherently limited to frequencies at which the electron transit time required for the beam electrons to traverse the distance between the deflectors and the anodes is substantially less than one-fourth cycle or 90° at the oscillation frequency. Thus, construction of a beam-deflection oscillator of this type for operation at V. H. F. and U. H. F. frequencies becomes quite inconvenient; small deflector-anode spacing which must be employed in tubes adapted to operate at reasonable electrode voltages makes it difficult to obtain sufficient transconductance.

Accordingly, it is a primary object of the invention to provide a new and improved oscillator for use at very-high or ultra-high frequencies which does not present the problems and difficulties noted above in connection with conventional devices.

It is a further object of the invention to provide a new and improved beam-deflection tube which is capable of satisfactory operation as an oscillator within the V. H. F. and U. H. F. frequency ranges.

It is an additional object of the invention to provide a new and improved oscillator utilizing a beam-deflection tube which is relatively simple and expedient to construct and economical to manufacture.

A beam-deflection oscillator constructed in accordance with the invention comprises an electron gun for projecting a sheet-like beam of electrons along a reference path and a pair of anodes disposed on opposite sides of that path in spaced relation to the electron gun. The oscillator further includes means for establishing a predetermined velocity for the electron beam comprising a pair of deflector electrodes disposed on opposite sides of the reference path intermediate the electron gun and the anodes, the centers of the deflectors being spaced from the anodes by a predetermined distance. A pair of conductive connector elements of negligible impedance at the desired operating frequency are included in the oscillator; each of these elements electrically connects one of the deflector electrodes to that one of the anodes which is disposed on the same side of the reference path. An inductive load interconnects the deflector electrodes to form therewith a resonant circuit having a resonance period substantially equal to twice the electron transit time of the electrons of the beam through the predetermined distance separating the deflectors and the anodes.

The features of the invention which are believed to be novel are set forth with particularity in the appended claims. The organization and manner of operation of the invention, together with further objects and advantages thereof, may best be understood by reference to the following description taken in conjunction with the accompanying drawing, in which the elements are identified by like numerals in each of the figures, and in which:

Figure 1 is a perspective view of the electrode system of an electron-discharge device constructed in accordance with the invention;

Figure 2 is a schematic representation of an oscillator constructed in accordance with the invention, comprising a cross-sectional view of an electron-discharge device including the electrode system of Figure 1, taken along line 2—2 therein; and

Figure 3 is a cross-sectional, partly schematic view of another embodiment of the invention.

As shown in the perspective view of Figure 1, the electrode system of a beam-deflection tube or electron-discharge device constructed in accordance with one embodiment of the invention comprises an elongated cathode 10, having an electron-emissive surface 11, and a focusing electrode 12 including a slot 13 which is centrally located with respect to emissive surface 11. An accelerating electrode 14 is included in the device and has a central aperture or slot 15 aligned with focusing-electrode slot 13.

Cathode 10 and electrodes 12 and 14 comprise an electron gun 16 for projecting a sheet-like beam of electrons along a predetermined path. The terminology "sheet-like beam of electrons," as used throughout this specification and in the appended claims, refers to an electron beam having one principal cross-sectional dimension which is very much greater than a second principal cross-sectional dimension; the term is not restricted to any particular cross-sectional configuration. Thus, a sheet-like beam may be of rectangular configuration in cross section with a thickness very much smaller than its width, or may be of generally ellipsoidal cross-sectional configuration, similarly elongated, or may be of annular or ring-like configuration with the radial thickness of the annulus very much smaller than the circumference. Consequently, it will be understood that the particular structure shown for elec-

tron gun 16 is purely illustrative and that any suitable structure for projecting a sheet-like beam in accordance with the definition given above may be employed without departing from the teaching of the invention.

A pair of deflector electrodes 17 and 18 are disposed adjacent opposite sides of slot 15 and are positioned intermediate accelerator 14 and a pair of anodes 19 and 20. A suppressor electrode 21 is positioned between anodes 19 and 20 and is aligned with slots 13 and 15. Anode 20 and deflector 18 are electrically connected by a conductive connector element 22; preferably, deflector 18, connector 22, and anode 20 are formed from a single continuous sheet of conductive material. A similar connector element 23 provides a direct electrical connection between anode 19 and deflector 17 (see Figure 2). Connectors 22 and 23 may be of considerably reduced height as compared to electrodes 17—20 in order to reduce the effective capacity between the deflector electrodes. Electrodes 12, 14 and 17—21 and connectors 22 and 23 may be formed from any of the many known conductive materials suitable for use in evacuated electron-discharge devices.

The electrode system of Figure 1 is shown in cross section in Figure 2, in which the normal or reference path of electrons from cathode 10 to anodes 19 and 20 is indicated by dash lines A. Cathode 10 is provided with an indirect heater element 24 (not shown in Figure 1) embedded in insulating material 25 and supported within the cathode sleeve. The entire electrode system is mounted within a suitable envelope 26, preferably a conventional miniature tube envelope, which is subsequently evacuated and gettered in any manner known in the art.

In the oscillator circuit illustrated in Figure 2, cathode 10 is connected to a source of reference potential, here indicated as ground, and focusing electrode 12 is also connected to ground. The grounding connection for the focusing electrode may be made within envelope 26 as illustrated or, if preferred, externally thereto. Accelerating electrode 14 is connected to a source of positive unidirectional bias potential B_2+ and suppressor 21 is connected to ground.

An inductive load comprising a coil 27 is connected across deflector electrodes 17 and 18 and may be provided with a variable tuning capacitor 28. The load circuit comprising inductor 27 and capacitor 28, in conjunction with the capacity between electrodes 17 and 18, forms a resonant circuit 29 having a predetermined resonance frequency, and, consequently, a predetermined resonance period. A source of unidirectional positive potential B_1+ is connected to the electrical center of inductor 27 to provide balanced bias potentials for anodes 19 and 20 as well as deflectors 17 and 18.

Preferably, the voltages supplied by sources B_1+ and B_2+ are of different values so that accelerator 14 and deflectors 17 and 18 are maintained at different D. C. potentials. This difference in bias potential between the accelerator and the deflectors leads to the formation of an electrostatic lens which may be employed to focus and direct the electron stream more accurately between electrodes 17 and 18. A sharply-focused electron beam is highly desirable in that the effective transconductance of deflector system 17, 18 with respect to anodes 19, 20 is directly dependent upon the width of the beam as it impinges upon the anodes. In other words, the voltage difference between deflectors 17 and 18 necessary to deflect the beam from one anode to the other is a direct function of the width of the beam as it strikes the anodes, so that the sensitivity of the device is materially increased by the use of a more accurately focused beam. Use of a more sharply focused beam also permits the utilization of a smaller seperation distance *d* between deflectors 17 and 18. Preferably, B_1+ is of lower potential than B_2+ in order to prevent the return of secondary electrons from anodes 19 and 20 to the electrodes of gun 16. It will be understood, of course, that individual potential sources B_1+ and B_2+ may be replaced by a single source of unidirectional positive potential having separate taps for different voltages and that coil 27 may be connected to anodes 19 and 20 or connectors 22 and 23 if preferred.

When the oscillator illustrated in Figure 2 is placed in operation, space electrons originating at emissive surface 11 of cathode 10 are focused by passing through slot 13 of electrode 12 and are accelerated as they traverse slot 15 in the electrode 14. The electron stream follows reference path A and passes between deflector electrodes 17 and 18, impinging upon anodes 19 and 20. Diversion of the total beam current to the two anodes is provided by suppressor 21, which is at a lower potential than the anodes. As in any conventional beam-deflection tube, the mean path of the beam from the effective center of deflection toward anodes 19 and 20 may be controlled by varying the potential difference between electrodes 17 and 18. If the potentials of the deflectors are equal, the beam divides substantially equally between anodes 19 and 20 and operation in this manner is indicated in the drawing for purposes of convenience. However, it may be desirable under certain circumstances to operate the beam-deflection tube under bias conditions in which there is a potential difference between deflectors 17 and 18 so that the path of the electron beam is displaced from original path A, and an arrangement of this type is entirely within the scope of the present invention. It should be noted that electrodes 17 and 18 are established at a positive potential with respect to cathode 10 so that the electrons emitted from surface 11 traverse the deflection system at a predetermined velocity corresponding to that potential.

The centers of deflection electrodes 17 and 18 are separated from the collecting-surface plane of anodes 19 and 20 by a predetermined distance D. For operation as an oscillator, resonant circuit 29 is tuned to a frequency having a resonance period which is substantially equal to twice the electron transit time required for the electrons of the beam to traverse distance D. Expressed differently, the centers of deflectors 17 and 18 are spaced from anodes 19 and 20 by the predetermined distance D which corresponds to an electron transit angle, for the velocity determined by the potential level of the deflectors, of approximately one-half cycle or 180° at the desired oscillation frequency. Theoretically, oscillation could be sustained for any electron transit angle between 90 to 270°; in practice, the transit angle must be considerably closer to the ideal one-half cycle.

Consider now that deflector electrode 18 is instantaneously positive with respect to deflector 17, so that the electron stream is deflected toward anode 20, as indicated by dash line A'. The deflected beam impinges only upon anode 20, which receives the full beam current; accordingly, anode 20 becomes negative with respect to anode 19. This change in the relative potentials of anodes 19 and 20 results in an immediate corresponding change in the relative potentials of deflectors 17 and 18, due to the direct conductive connections provided by connectors 22, 23 between each of the anodes and the deflector positioned on the same side of path A. To achieve this effect, of course, conductive connectors 22, 23 must be of negligible impedance at the desired operating frequency of the oscillator. Consequently, deflector 17 becomes positive with respect to deflector 18 and the sense of the beam deflection is reversed so that it strikes only anode 19. Anode 19 then becomes negative with respect to anode 20 and the respective polarities of deflectors 17 and 18 are again reversed. Thus, each time that one of the deflector electrodes goes positive with respect to the other deflector, the beam is deflected in a direction such that it causes a subsequent reversal of deflection.

However, as indicated above, a period of time approximately equal to one-half the resonance period of circuit

29 is required for the electrons of the stream to traverse distance D between the center of deflection and anodes 19, 20. As a result, the sense of the beam deflection reverses twice during a time interval equal to the period of the resonant circuit and the alternation of the beam between anodes 19 and 20 establishes and sustains an oscillatory current in circuit 29.

The versatility and efficiency of the oscillator illustrated in Fig. 2 may best be shown by means of a specific example, which is included merely by way of illustration and by no means as a limitation on the inventive concept. A beam-deflection tube has been constructed in accordance with Figures 1 and 2 and employed as an oscillator operable over the U. H. F. frequency range. The deflector length h (see Figure 2) was 0.135" and distance D was 0.160". The total height of electrodes 10, 12, 14 and 17—20 was nine-sixteenths inch. When incorporated in an oscillator essentially identical with that of Figure 2, the tube provided oscillation over a range from 340 to 1000 megacycles, despite the fact that the reactance/resistance ratio or Q of circuit 29 was only approximately 60. For 1000-megacycle operation, the biasing potentials employed were 225 volts for anodes and deflectors and 720 volts for the accelerator. With 130 volts on deflectors and anodes and between two and three milliamperes of beam current, oscillation was maintained over a band of frequencies ranging from 340 to approximately 700 megacycles, a ratio slightly exceeding two to one. These particular figures for a specific device and circuit demonstrate the wide high-frequency range over which the oscillator may be operated.

Figure 3 illustrates an oscillator which is in many respects identical with that of Figure 2; the structure of electron gun 16, deflectors 17 and 18 and connectors 22 and 23 is the same as that of the previously-described embodiment. In the oscillator of Figure 3, however, anode 19 is extended so that it terminates approximately at the center line of the electrode system, which corresponds to original beam path A. Anode 20, on the other hand, is terminated a very small distance from path A, and an extension 30, which forms a part of anode 20, projects across the reference path behind anode 19. Resonant circuit 29' is modified to include a parallel-wire inductive circuit 31 which is terminated by variable capacitor 28. Separate leads 33 and 34 are provided for anodes 19 and 20 respectively and are connected to bias source B_1+ through a pair of individual choke coils 35 and 36. In addition, a separate external lead 37 is provided for focusing electrode 12.

As in the embodiment of Figure 2, the electrons following path A impinge in substantially equal numbers upon anode 19 and extension 30 of anode 20; accordingly, static conditions are the same as for the electrode system of Figures 1 and 2. As before, the beam velocity is adjusted so that the electrons traverse distance D between the center of deflection and anodes 19 and 20 in a time interval approximately corresponding to one-half cycle at the resonance frequency of circuit 29'. Operation of the oscillator of Figure 3 is thus in all essential respects identical with that of Figure 2, so that a repetition of the operational description of the device is deemed unnecessary.

For ordinary oscillator operation, lead 37 is grounded. However, if it is desired to amplitude-modulate the output signal of the oscillator, lead 37 may be connected to a modulating signal source 38 so that a suitable modulating signal may be applied to electrode 12. On the other hand, if frequency-modulation of the oscillator signal is found desirable, the modulating signal may be superimposed upon the anode biasing potential B_1+. Because such a signal varies the potential on deflectors 17 and 18, it modifies the velocity of the electron stream and therefore causes variations in the transit time of the electrons traversing distance D. The average operating frequency of the device is determined by the resonant frequency of circuit 29', and the applied signal frequency-modulates the current in the oscillator circuit.

In order to obtain oscillation at relatively low beam current, deflector length h should be considerably larger than the space d between the deflectors. A high aspect ratio (h/d) limits the amplitude of the oscillatory current to a rather low level, since the electron beam is intercepted by the trailing ends of electrodes 17 and 18 whenever the voltage between the deflector electrodes exceeds a predetermined level. This low-level amplitude-limiting characteristic is highly desirable for many local oscillator applications; a lower aspect ratio permits higher-amplitude oscillation current but also requires more beam current to sustain oscillation. For effective operation, deflector length h should not greatly exceed the distance traversed by the electron beam during a time interval equal to one-half the resonance period of circuit 29.

Although the circuitry of the oscillators of the invention is extremely simple, they provide oscillation over a wide range of frequencies much higher than those obtainable in conventional beam-deflection oscillators using comparable voltages and electrode dimensions. In addition, if a more compact oscillator is desired, the inductive load represented by coil 27 may be formed as part of the electrode system and included within envelope 26. It should be noted that accelerator 14 may be omitted from gun 16, in which case the leading edges of deflectors 17 and 18 serve as accelerators for the electron beam; however, the illustrated construction is preferred where a high deflector-anode transconductance is desired. The electrode structures of the beam-deflection tubes are extremely simple in configuration and the electrodes are relatively few in number; all of the electrodes may be manufactured from thin metallic sheets by punching or similar inexpensive mass-production techniques. The spacing between the various electrodes is not particularly critical from a manufacturing standpoint and permits the utilization of reasonable dimensional tolerances. In addition, and for the same reasons, variations in the spacing between electrodes which may result from changes in thermal operating conditions do not adversely affect the stability of the oscillator.

While particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the invention in its broader aspects. Accordingly, the aim in the appended claims is to cover all such changes and modifications as may fall within the true spirit and scope of the invention.

I claim:

1. A beam-deflection oscillator adapted for operation over a predetermined range of frequencies, said oscillator comprising: an electron gun for projecting a sheet-like beam of electrons along a reference path; a pair of anodes disposed on opposite sides of said reference path in spaced relation to said electron gun; means for establishing a predetermined velocity for said beam comprising a pair of deflector electrodes disposed on opposite sides of said reference path intermediate said electron gun and said anodes, the centers of said deflectors being spaced from said anodes by a predetermined distance; a pair of conductive connector elements of negligible impedance over said predetermined range of operating frequencies, each of said elements electrically connecting one of said deflector electrodes to that one of said anodes disposed on the same side of said reference path as said one deflector electrode; and an inductive load interconnecting said deflector electrodes to form therewith a resonant circuit having a resonance frequency within said range and a resonance period substantially

equal to twice the electron transit time of the electrons of said beam through said predetermined distance.

2. A beam-deflection oscillator adapted for operation over a predetermined range of frequencies, said oscillator comprising: an evacuated envelope; an electron gun mounted within said envelope for projecting a sheet-like beam of electrons along a reference path; a pair of anodes disposed within said envelope on opposite sides of said reference path in spaced relation to said electron gun; a suppressor electrode disposed within said envelope between said anodes; means for establishing a predetermined velocity for said beam comprising a pair of deflector electrodes disposed within said envelope on opposite sides of said reference path intermediate said electron gun and said anodes, the centers of said deflectors being spaced from said anodes by a predetermined distance; a pair of conductive connector elements of negligible impedance over said predetermined range of operating frequencies disposed within said envelope, each of said elements electrically connecting one of said deflector electrodes to that one of said anodes disposed on the same side of said reference path as said one deflector electrode; and an inductive load interconnecting said deflector electrodes to form therewith a resonant circuit having a resonance frequency within said range and a resonance period substantially equal to twice the electron transit time of the electrons of said beam through said predetermined distance.

3. A beam-deflection electron-discharge device for generating electrical oscillations of a given frequency comprising: an electron gun for projecting a sheet-like beam of electrons along a reference path; a pair of anodes disposed on opposite sides of said reference path in spaced relation to said electron gun; means for establishing a predetermined velocity for said beam comprising a pair of deflector electrodes disposed on opposite sides of said reference path intermediate said electron gun and said anodes, the centers of said deflectors being spaced from said anodes by a predetermined distance corresponding to an electron transit angle at said predetermined velocity of approximately one-half cycle at said oscillation frequency; and a pair of conductive connector elements of negligible impedance at said oscillation frequency, each of said elements electrically connecting one of said deflector electrodes to that one of said anodes disposed on the same side of said reference path as said one deflector electrode.

4. A beam-deflection electron-discharge device for generating electrical oscillations of a given frequency comprising: an electron gun for projecting a sheet-like beam of electrons along a reference path; a pair of anodes disposed on opposite sides of said reference path in spaced relation to said electron gun; means for establishing a predetermined velocity for said beam comprising a pair of deflector electrodes disposed on opposite sides of said reference path intermediate said electron gun and said anodes, the centers of said deflectors being spaced from said anodes by a predetermined distance corresponding to an electron transit angle at said predetermined velocity of approximately one-half cycle at said oscillation frequency; and a pair of connector elements of negligible impedance at said oscillation frequency, each of said elements electrically connecting one of said deflector electrodes to that one of said anodes disposed on the same side of said reference path as said one deflector electrode, each said connector element with its associated anode and deflector electrode being formed from a single continuous sheet of conductive material.

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