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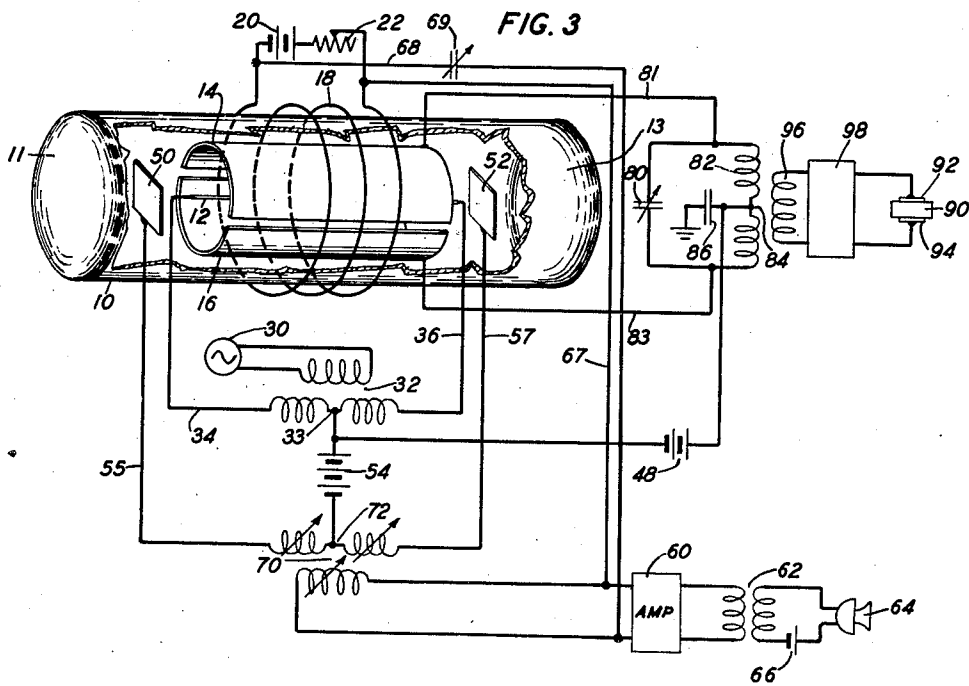
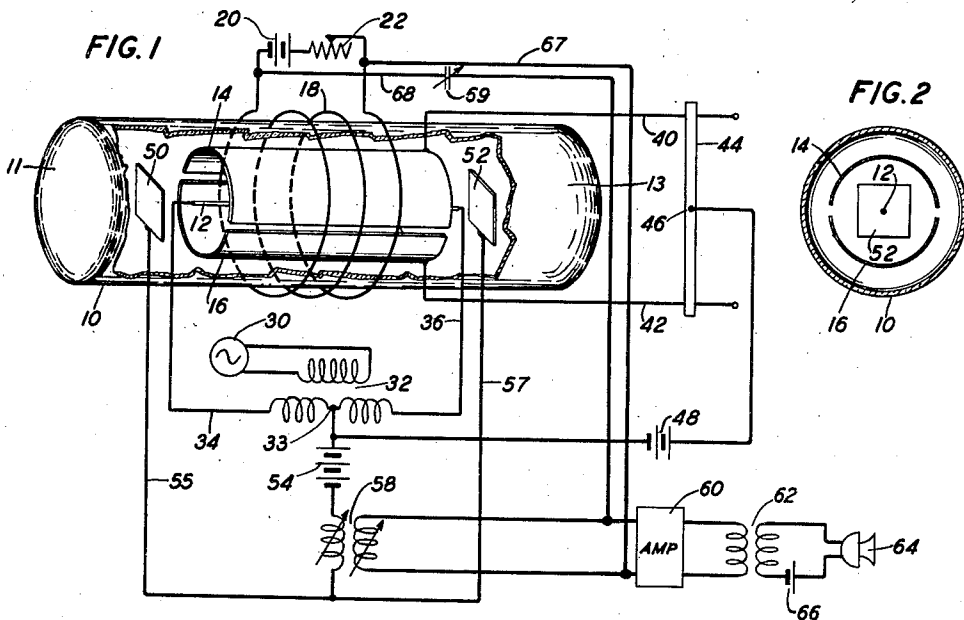
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2,122,495

MAGNETRON OSCILLATOR

Filed May 29, 1935

3 Sheets-Sheet 1



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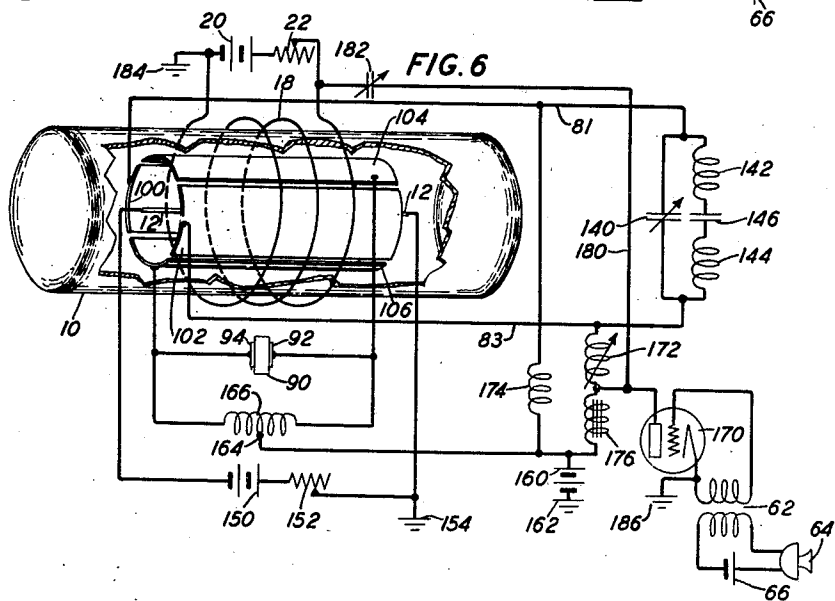
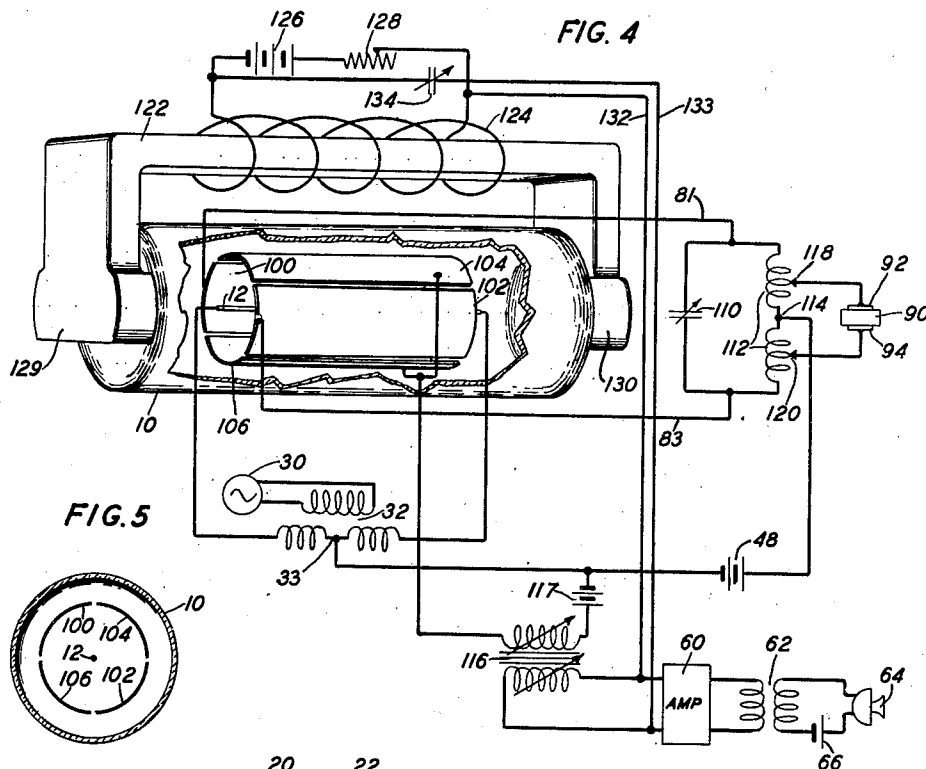
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MAGNETRON OSCILLATOR

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3 Sheets-Sheet 2



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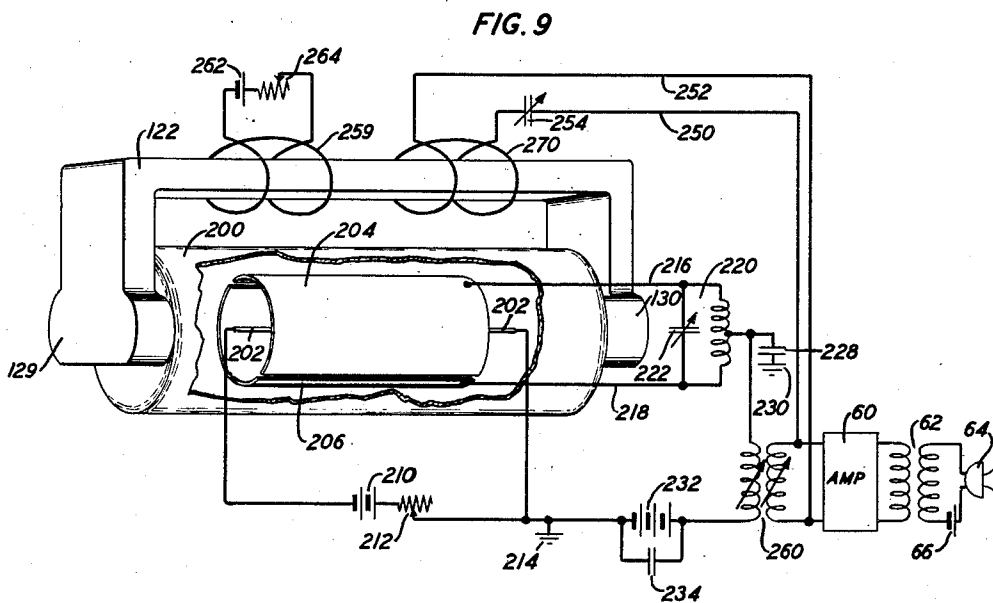
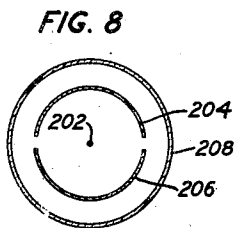
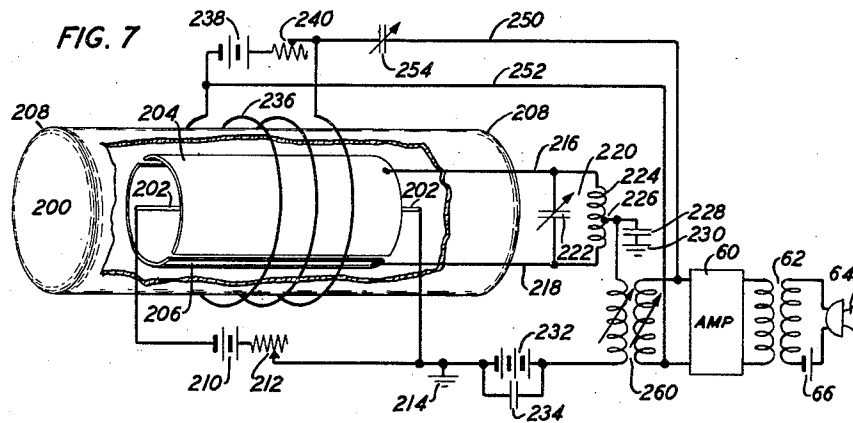
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MAGNETRON OSCILLATOR

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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,122,495

MAGNETRON OSCILLATOR

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Application May 29, 1935, Serial No. 24,060

14 Claims. (Cl. 179—171)

This invention relates to oscillation generators and particularly to high frequency oscillation generators of the so-called magnetron type wherein magnetic and electrostatic fields are employed to control the flow of electrons between a cathode and an anode disposed within an envelope or container.

One of the objects of this invention is to protect such an envelope from destructive bombardment by electrons.

Another object of this invention is to influence the output oscillations of a high frequency oscillation generator and to obtain greater efficiency of operation thereof.

Another object of this invention is to so modulate the radio frequency output oscillations of an oscillation generator in accordance with signals as to reduce distortion.

Another object of this invention is to control or stabilize the frequency of the oscillations generated by a magnetron oscillator.

A magnetron oscillator may comprise circuits including a tube containing a suitable gas at a suitable pressure and also containing an electron-emitting cathode element and an anode element comprising one or more anode plates, and means for producing a magnetic field transverse to the path of electrons between the cathode and anode structure. By coupling or connecting a tuned output circuit to the anode structure or to the anode and cathode elements, under proper conditions of cathode heating, anode potential and strength of magnetic field, oscillations of the desired frequency or wave-length may be set up in the tunable output circuit.

The envelope may be evacuated to such degree that there is no appreciable gas ionization, or is substantially free of gas ionization, in the space inclosed by the envelope. The cathode may be of the cold cathode type or of the heated type in the form of a linear or straight filament held taut as by a tension spring, coated with a suitable electron emission surface, and heated directly or indirectly by a suitable source of alternating or direct current energy. The anode may be cylindrical in shape and disposed concentric with the cathode or filament, and may consist of a single plate or of multiple plates which may be curvilinear in shape or otherwise and which may be split or non-split. The magnetic field may be unidirectionally produced by an electromagnet having an iron core to concentrate the magnetic field and may be adjustable to produce a glancing incidence of electrons with respect to the anode. The tuned output circuit or antenna

may be of any suitable type and if desired, of critical length with respect to the wave-length of the waves developed thereon.

If a grid control element be added to the magnetron oscillator, the output power may be increased or the filament current required to produce a given output power may be reduced.

To increase the output power from the oscillator, the axis of the tube anode-cathode structure or system may be angularly tilted or inclined to a non-coaxial relationship with respect to the direction of the axis of the magnetic field. The angular adjustment may be obtained by tilting the tube system with respect to the magnetic field or vice versa. The optimum adjustment angle may be between zero and about 15 degrees on either side of the zero or coaxial position of axes. The angle may be so adjusted to a relationship where the maximum radio frequency output is obtained.

Auxiliary electrode structure, suitably polarized, may be provided to control or influence the field and electron flow as by distorting the field and changing the path of the electrons for such several purposes as to increase the oscillator output power and efficiency, to modulate the oscillator output in accordance with signals, to stabilize the output frequency of the magnetron oscillator, or to prevent destructive bombardment of the glass envelope inclosing the anode-cathode structure.

The auxiliary electrode structure may be in the form of one or more metal plates of suitable size disposed endwise of or at or adjacent the ends of the cathode-anode structure along the axis of the magnetic field. The metal end plates may be built into the structure of the tube and disposed within the glass envelope or they may be attached to the outside or inside of the glass envelope.

Such end plate auxiliary electrode structure may be employed as electrostatic means so polarized as to increase the output power of an oscillator especially when operating at very short wave-lengths or to increase the space charge of an electron discharge device or to control the direction and value of current and field therein. The current between the end plates and filament may be reversed in direction by applying a sufficiently high negative potential to the end plates. If negative potential is supplied to the end plate structure, the electrons are repelled thereby. If positive potential is supplied to the end plate structure, the electrons are drawn toward the end plate structure. In either case, an axial com-

ponent of motion of the electrons is produced.

The end plates may be suitably polarized to increase the output power and efficiency of the oscillator. When the tube is oscillating and delivering power to the load or output circuit, if the voltage applied to the end plates is made increasingly positive, an increase of radio frequency output power delivered to the load is obtained. The values of voltage applied to the end plates may be adjusted to secure the optimum value of increased power output.

The end plate auxiliary electrodes may be maintained at a moderately high negative potential with respect to filament to repel or turn back electrons moving in their direction for such purpose as to prevent bombardment or sputtering of the glass envelope. Such bombardment may take place on the interior of the glass wall and the impact may be so intense that the glass in a small circular portion may be chipped or broken or a small hole produced in the glass. Surrounding this portion and extending over quite an area, the glass may be sputtered with a coating which may vary in color from a coffee color to a grey. Such bombardment may take place on diametrically opposite parts of the tube wall but not necessarily in a coaxial line with the filament especially when the axis of the magnetic field is angularly displaced with respect to the axis of the plate-filament structure.

Signal responsive potentials may be applied to the end plate structure to modulate the radio frequency output of the oscillator in accordance with such signals.

A multiple plate magnetron may be provided having four quarter-cylindrical plates or segments disposed longitudinally of and concentric with a filament. Two of the plates, oppositely disposed and operating as an anode, may be connected to the oscillating system and the remaining two plates, also oppositely disposed, interspaced between the first-mentioned plates and operating as auxiliary electrodes may have modulating voltage impressed thereupon to distort the electric field and redistribute the electron flow to produce modulation of the oscillating system in accordance with telephone or telegraph signals.

The output oscillations may be modulated in accordance with signals not only through the plate structure alone, such as the anode plate structure or the end plate structure or other auxiliary electrode structure, but also through the magnetic field alone, or by a combination of magnetic field and plate modulation from the same signal current source wherein the signal currents from the same or common source may be so adjusted in phase and magnitude as to reduce distortion in the modulated oscillations.

A mechanical vibratile element in the form of a piezoelectric quartz crystal may be employed if desired, as by coupling with the output circuit or in connection with one or more of the plate electrodes, to control or stabilize the frequency of the oscillations generated by the magnetron oscillator in accordance with a frequency characteristic, fundamental or harmonic, of the crystal.

Where the magnetron anode has more than one anode plate, one of the anode plates may be maintained at constant potential and the potential of another anode plate may be modulated in accordance with signals, thereby leaving full voltage on at least one anode plate. This arrangement may be utilized to render the circuit

more stable and less likely to stop oscillating.

For a clearer understanding of the nature of this invention and the additional features and objects thereof, reference is made to the following description taken in connection with the accompanying drawings, in which like reference characters in the various figures indicate the same parts, and in which

Fig. 1 is a diagram showing an end plate form of magnetron oscillator;

Fig. 2 is a sectional end view of the envelope, cathode, anode, and auxiliary electrode structure of Fig. 1;

Fig. 3 is a diagram showing a modification of Fig. 1;

Fig. 4 is a diagram showing another modification of a magnetron oscillator;

Fig. 5 is a sectional end view of the envelope, cathode, anode, and auxiliary electrode structure of Fig. 4;

Fig. 6 is a diagram showing a modification of Fig. 4;

Fig. 7 is a diagram showing another modification of an oscillation generator;

Fig. 8 is an end view in vertical section of the tube shown in Fig. 7; and

Fig. 9 is a diagram showing a modification of Fig. 7.

Fig. 1 shows a magnetron oscillator including a space discharge device having an envelope or container 10 constructed of glass, quartz or other suitable material, an electron-emitting cathode 12 of the heated filament type, and an anode structure comprising a pair of semi-cylindrical anode plates 14 and 16, and means for producing a unidirectional magnetic field comprising a field coil 18, a battery 20 and a variable resistance 22. The envelope 10 is preferably evacuated to such degree that there is no appreciable gas ionization in the space inclosed by the envelope 10. Such condition of evacuation is usually referred to as a high vacuum.

The electron-emitting cathode 12 may be of tungsten or other suitable material, preferably disposed axially and centrally with respect to the anode plates 12, 14 and the envelope 10, and heated by a suitable adjustable source of current such as an alternating current source 30. Alternating current from the source 30 may be supplied to the filament 12 by a circuit including a transformer 32 and lead-in wires 34 and 36. The linear or straight-wire filament 12 may be coated with a suitable electron-emission surface.

The anode structure consisting of the semi-cylindrical plates 14 and 16 may be constructed of tungsten or other suitable metal and is preferably arranged, as shown, in circular symmetry and concentric with respect to the linear cathode 12. While the anode structure of Fig. 1 is shown in two semi-cylindrical spaced sections or plates 14 and 16, it will be understood that the anode may be a single plate anode of the split or non-split type or may be a multi-plate anode having two or more anode plates.

The magnetic field coil 18 is supplied with unidirectional current from the battery 20, the current being adjusted by the variable resistance 22 to adjust the magnetic field strength to a suitable value such as to produce glancing incidence, or less than glancing incidence, of electrons with respect to the anode plates 14 and 16. In the case of less than glancing incidence of electrons with respect to the anode plates 14 and 16, the

electrons may be turned back when they travel part of the way between the cathode 12 and the anode plates 14 and 16. The magnetic field coil 18 is shown as having an air core but, if desired, an iron core may be employed to concentrate the magnetic field as shown in Fig. 4. The direction of the axis of the magnetic field produced by the field winding 18 is transverse to the path of electrons between the cathode 12 and the anode structure 14, 16, and substantially parallel to the cathode and anode structure 12, 14, and 16. It will be understood, however, that the axis of the structure or system comprising the tube 10, the cathode 12 and the anode plates 14 and 16 may be angularly tilted or inclined to a non-coaxial relationship with respect to the direction of the axis of the magnetic field produced by the field coil 18 to increase the output power from the system. Such angular inclination to obtain the optimum value of increased power output is usually somewhere between zero and 15 degrees on either side of the zero or coaxial position of the tube system axis and magnetic field axis.

Connected with the anode plates 14 and 16, there is shown a Lecher wire system which may consist of copper pipes or wires 40 and 42 disposed in parallel spaced relationship and bridged by an antenna 44 which is slidably adjusted along the length of the two parallel conductors 40 and 42. By suitable adjustment of the bridge 44 along the length of the conductors 40 and 42, the system may be turned to a desired wave-length, as a wave-length of about one meter, for example. While in Fig. 1, the anode plates 14 and 16 are shown connected with the Lecher wire system 40 and 42, it will be understood that the tunable output circuit may be connected with any suitable antenna system or radiating system. The bridge 44 is connected at its midpoint 46 with the positive terminal of an adjustable source of direct current in the form of a battery 48. The negative terminal of the battery 48 is connected with the midpoint 33 of the transformer 32. The battery 48 is adapted to furnish a high positive voltage to the anode plates 14 and 16. Under proper conditions of heating of the cathode 12 and suitable potential applied to the anode plates 14 and 16 from the source 48 and proper adjustment of the strength of the magnetic field from the field coil 18, oscillations of the desired frequency or wave-length may be set up in the tunable output circuit 40, 42, and 44. The magnetic field produced by the winding 18 and the electrostatic field produced by the anode plates 14 and 16 are employed to control a flow of electrons between the cathode 12 and the anode plates 14 and 16. Tuning the output circuit increases the strength of the oscillations.

Auxiliary electrode structure in the form of a pair of equal size rectangular-shaped end plates 50 and 52 disposed at right angles to the axis of the cylindrical anode 14, 16 and suitably polarized from a battery 54 is provided to control or influence the electron flow between the cathode 12 and the anode plates 14 and 16 by producing an axial component of motion of the electrons with respect to the axis of the tube system 10, 12, 14, and 16. The auxiliary electrodes 50 and 52 are disposed endwise of or at or adjacent the ends of the cathode and anode structure 12, 14, and 16 and may be built into the tube structure and disposed within the glass envelope 10. The end plates 50 and 52 may be constructed of any suitable conductive material and may be attached to the outside or inside of the glass envelope 10,

if desired, and disposed at a suitable distance from the cathode 12 along the axis of the magnetic field produced by the field winding 18.

When the end plates 50 and 52 are suitably polarized as from a battery corresponding to the battery 54, they may operate as electrostatic means to increase the space charge of the electron discharge device 10 and to increase the output power of the oscillating system. For example, when the system is oscillating and delivering power to the load circuit 40, 42, and 44, if the voltage from the source 54 applied to the auxiliary end plates 50 and 52 is made of suitable positive value with respect to the filament 12, an increase of radio frequency output power delivered to the load circuit of the magnetron oscillator may be obtained. A magnetron of the type shown in Fig. 1 oscillating at a wave-length of 1.5 meters may have a potential of the order of 1000 volts applied to the anode plates 14 and 16 from the source 48, suitable magnetic field strength from the winding 18, and a voltage from the source 54 applied to the auxiliary end plates 50 and 52 of the order of several hundred volts with respect to the filament 12. It will be understood that the values of voltage applied from the source 54 to the end plates 50 and 52 may be adjusted to secure the optimum value of increased output power in the load circuit 40, 42, and 44.

If the end plate auxiliary electrodes 50 and 52 are maintained at a moderately high negative potential, for example, of the order of 200 volts with respect to the filament 12, the electrons are turned back and repelled and destructive bombardment or sputtering of the ends 11 and 13 of the glass envelope 10 by electrons may be prevented. Such bombardment may take place at diametrically opposite parts 11 and 13 of the tube 10 in a line corresponding very roughly to the axis of the magnetic field. The end plates 50 and 52 suitably polarized may be utilized to protect the glass envelope 10 from such bombardment and sputtering.

Means may be provided for modulating in accordance with signals the radio frequency output oscillations of the magnetron oscillator shown in Fig. 1. The modulating potentials may be supplied to the end plates 50 and 52 through a circuit including the conductors 55 and 57, a transformer 58, an audio frequency amplifier 60, an audio frequency transformer 62, a telephone transmitter or microphone 64 and a battery 66. Signals, such as voice signals, impressed upon the telephone transmitter 64 supply corresponding potentials to the auxiliary electrodes 50 and 52 and operate to modulate the radio frequency output of the oscillation generator.

The modulating potentials may be impressed not only upon the end plates 50 and 52 alone as described, but also upon the magnetic field producing winding 18 by means of a circuit including the conductors 67 and 68 and a condenser 69 thereby to produce a combined simultaneous plate and magnetic field modulation from the same or common signal source 64. The phase and magnitude relations of the modulation potentials supplied from the common signal source 64 to the end plates 50 and 52 and to the winding 18 may be so adjusted, as by means of the variable inductance 58 and the variable condenser 69, as to reduce signal distortion by producing a linear relation between the change in amplitudes of the radio frequency modulation and the signal voltage modulation thereby to secure straight line amplitude modulation of the radio frequency oscillations.

tions at a region where substantially no frequency modulation occurs.

It will be understood that, by disconnecting the coupling transformer 58, for example, the radio frequency output oscillations may be modulated through the magnetic field alone as by impressing the signal modulated voltages upon the winding 18 over the circuit including the conductors 67 and 68 and the condenser 69. The end plates 50 and 52 may at the same time be utilized as hereinbefore described for producing an axial component of motion the electrons for the several purposes mentioned.

Fig. 2 shows a sectional end view of the auxiliary electrode and cathode-anode structure of Fig. 1. It will be understood that the end plate electrodes 50 and 52 may be of circular or rectangular shape or other suitable shape and dimensions.

Fig. 3 shows a modification of the system shown in Fig. 1. The space discharge device including the cathode 12, anode plates 14 and 16 and end plates 50 and 52 as shown is similar to that shown in Fig. 1. An alternative modulation connection is shown in Fig. 3 wherein modulating potentials varying in accordance with signals may be supplied to the end plates 50 and 52 from the telephone transmitter 64 by means of a transformer 70 having a midpoint 72 of one of its windings connected with the battery 54.

The modulating potentials may be impressed not only upon the end plates 50 and 52, but also upon the magnetic field producing winding 18 by means of a circuit including the conductors 67 and 68 and the condenser 69 to produce simultaneous plate and magnetic field modulation from the same source 64. The signal modulating potentials may be so adjusted in phase and magnitude as to reduce signal distortion and frequency modulation as by suitable adjustments in the variable inductance 70 and the variable condenser 69. By disconnecting the coupling transformer 70, for example, the radio frequency oscillations may be modulated in accordance with signals through the magnetic field alone over the circuit including the conductors 67 and 68 and the condenser 69.

An alternative tunable output circuit is shown in Fig. 3 which comprises a variable condenser 80 connected in parallel circuit relation with a winding 82 having a midpoint 84 connected with the battery 48 and connected to ground through a condenser 86. The tunable output circuit 80, 82 is connected with the anode plates 14 and 16 through the conductors 81 and 83.

A mechanical vibratile element in the form of a piezoelectric quartz crystal 90 having electrodes 92 and 94 may be coupled through a winding 96 to the winding 82 for controlling or stabilizing the frequency of the oscillations generated in the tunable output circuit 80, 82. Additional circuits or devices, such as amplifier tubes, may be provided as indicated at 98.

Figs. 4 and 5 show a multiple plate magnetron oscillator tube 10 having four quarter-cylindrical spaced plates or segments 100, 102, 104, and 106 preferably disposed longitudinally of and concentric with a filament cathode 12. Two of the plates, namely, anode plates 100 and 102 oppositely disposed and operating as an anode, are connected by conductors 81 and 83 with a tunable oscillating system including a variable condenser 110 and a winding 112 having a midpoint 114 which is connected with the positive terminal of the battery 48. The negative terminal of the battery 48 is connected with the midpoint 33 of

the transformer winding 32 as in Fig. 1. The remaining two plates, namely, auxiliary plates 104 and 106, are also oppositely disposed with respect to each other and are interspaced between the anode plates 100 and 102 and may have modulating voltage impressed thereupon from the telephone transmitter 64 through a circuit including an audio frequency transformer 116, thereby producing modulation of the oscillating system in accordance with signals by distorting the electric field and redistributing the electron flow between the cathode 12 and the anode plates 100 and 102.

A source of voltage in the form of a battery 117 having one terminal thereof operatively connected with the cathode 12 and having another terminal thereof connected with the modulating transformer 116, may supply positive voltage of suitable value to the modulating plates 104 and 106 independently of the value of voltage supplied to the oscillator plates 100 and 102 from the battery 48.

A piezoelectric quartz crystal 90 may be connected, if desired, with the anode plates 100 and 102 through adjustable taps 118 and 120 on the winding 112 to stabilize the frequency of the oscillations generated.

An iron core 122 may be employed in connection with a magnetic field producing winding 124 for the purpose of concentrating the magnetic field produced thereby. The winding 124 may be energized from a battery 126 controlled by a variable resistance 128. The poles 129 and 130 of the magnet core 122 produce a magnetic field in a direction converse to the path of electrons between the cathode 12 and the anode plates 100 and 102.

In Fig. 4, it will be noted that radio frequency oscillations in the output circuit including the anode plates 100 and 102 and the tunable output circuit 110 and 112 may be modulated through the auxiliary electrodes 104 and 106 by signals impressed upon the telephone transmitter 64. The modulating potentials may be impressed either upon the auxiliary plates 104 and 106 alone or upon the auxiliary plates 104 and 106 in combination with the magnetic field producing winding 124 by means of a circuit including conductors 132 and 133 and a condenser 134, thereby to produce simultaneous or combination plate and magnetic field modulation from the same or common source 64. The modulating potentials from the common source 64 may be so adjusted in phase and magnitude as to reduce signal distortion and frequency modulation by suitable adjustments in the variable inductance 116 and the variable condenser 134, for example. If desired, the radio frequency oscillations may be modulated in accordance with signals through the magnetic field alone over the circuit including the conductors 132 and 133 and the condenser 134.

Fig. 6 shows a multiple plate magnetron oscillator tube 10 having four quarter-cylindrical spaced plates 100, 102, 104, and 106 preferably disposed longitudinally of and concentric with a filament cathode 12. To stabilize the frequency of oscillations, a piezoelectric quartz crystal 90 may be connected in the auxiliary electrode circuit which includes the auxiliary electrodes 104 and 106. The anode plates 100 and 102 are connected with the tunable output or load circuit including a variable condenser 140, windings 142 and 144 and a condenser 146. The filament cathode 12 which is grounded at 154 may be energized by direct current from a battery 150 con-

trolled by a variable resistance 152. The magnetic field-producing means illustrated is of the air core type like that shown in Fig. 1. A battery 160 has its negative terminal connected to ground at 152 and its positive terminal connected to the anode plates 100 and 102 and also to the auxiliary electrodes 104 and 106 through the midpoint 164 of the radio frequency choke coil 166, the latter being connected in parallel circuit relationship with the quartz crystal 90 and the auxiliary electrodes 104 and 106.

The radio frequency output of the magnetron oscillator shown in Fig. 6 may be modulated by signals impressed on the transmitter or microphone 64. The modulation system shown is of the constant current type modified to change the potential on the anode plate 102 only, full potential being maintained on the other anode plate 100. For this purpose there is provided between the transmitter 64 and the anode plates 100 and 102, an amplifier 170, which may be used to amplify signal currents from the transmitter 64, a radio frequency choke coil 172 adapted to transmit audio frequency currents from the amplifier 170 to the plate 102, another radio frequency choke coil 174, and an audio frequency choke coil 176 which is adapted to obstruct audio frequency currents from the amplifier 170 thereby preventing such currents from affecting the anode plate 100. The anode plate 100 is therefore maintained at constant potential and the potential of the anode plate 102 is varied in accordance with the signals impressed on the transmitter 64. By leaving full voltage on at least one anode plate, which in this instance is the anode plate 100, the circuit may be rendered more stable and less likely to stop oscillating abruptly.

Combined plate and magnetic field modulation in accordance with signals may be obtained by impressing the signal modulated potentials or currents upon the magnetic field producing winding 18 by means of a circuit including a conductor 180, a condenser 182 and a ground return circuit 184, 186, thereby to produce simultaneous anode plate and magnetic field modulation from the common signal source 64. The modulating potentials from the common source 64 may be so adjusted in phase and magnitude as to reduce distortion by suitable adjustments in the variable inductance 172 and the variable condenser 182, for example.

Figs. 7 and 8 shows a magnetron oscillation generator which includes a space discharge device 200 having a cathode 202 of any suitable type and two spaced semi-cylindrical anode plates 204 and 206 preferably arranged concentrically with respect to the cathode 202 and disposed within an evacuated envelope 208. The cathode 202 may be heated by current from a battery 210 controlled by a variable resistance 212 or other suitable means. The cathode 202 may be grounded at 214. The anode plates 204 and 206 may be connected by conductors 216 and 218, respectively, with a suitable output circuit as a tunable output circuit 220 comprised of a variable tuning condenser 222 and an inductance coil 224 having a midpoint 226 connected with a condenser 228 grounded at 230. The midpoint 226 of the coil 224 may be also connected with a battery 232 to polarize the anode plates 204 and 206 at a suitable positive potential. A by-pass condenser 234 serves to by-pass alternating currents. A winding 236 surrounding the envelope 208 may be energized by a battery 238 and controlled by a variable resistance 240 to produce a magnetic field

for controlling the electron flow between the cathode 202 and the two anode plates 204 and 206.

By suitable adjustments of the magnetic field strength, cathode current, polarizing voltage upon the anode plates 204 and 206 and tuning condenser 222, radio frequency oscillations of the desired frequency may be set up in the tunable output circuit 220 and modulated in accordance with telephone or telegraph signals impressed on a signal responsive circuit as a circuit including the telephone transmitter or microphone 64, the battery 66, the transformer 62 and the audio frequency amplifier 60.

The radio frequency output oscillations may be modulated through the magnetic field alone by impressing modulating voltages varying in accordance with signals upon the winding 236 that produces the magnetic field. For this purpose, the winding 236 may be connected with the circuit of microphone 64 by means of conductors 250 and 252 and a condenser 254. Signals such as speech impressed on the microphone 64 produce signal currents which may be amplified by the amplifier 60 and introduced into the winding 236 by means of the conductors 250, 252 and the condenser 254 to impress modulating voltages varying in accordance with the signals upon the winding 236 thereby to influence the magnetic field produced by the winding 236 to modulate the oscillations generated in accordance with the signals impressed on the microphone 64.

Plate modulation alone on both anode plates 204 and 206 of the oscillation generator of Fig. 7 may be obtained by coupling the signal source 64 with the anode plates 204 and 206 by means of a transformer 260 and disconnecting the magnetic field winding 236 from the signal source 64. By means of the circuit including the coupling transformer 260 and the coil 224, modulating voltages varying in accordance with telephone signals on the microphone 64 are impressed on both anode plates 204 and 206 thereby to modulate the oscillations generated in accordance with signals.

Combined plate and magnetic field modulation of oscillations generated may be obtained with the system shown in Fig. 7 wherein modulating voltages varying in accordance with signals in the same or common signal circuit 64 may be impressed not only upon the winding 236 which produces the magnetic field, but also upon the anode plates 204 and 206 thereby to produce a combined simultaneous plate and field modulation of oscillations generated in accordance with signals impressed on the same source 64.

By suitable adjustment of the phase and amplitude relation of the modulating voltages on the plates 204, 206 and field winding 236, as for example, by adjustment of the variable condenser 254 or the variable coupling transformer 260 or both, such relation as a linear relation between the radio frequency amplitude and the modulating voltage amplitude may be obtained that a modulation of the signal voltages is accompanied by a corresponding modulation of the radio frequency output oscillations thereby to reduce distortion of signals and secure straight line amplitude modulation at a point where no frequency modulation occurs.

Fig. 9 shows a modification of Fig. 7, like reference characters indicating similar parts. In Fig. 9, a winding 259 energized by a battery 262 controlled by a variable resistance 264 produces

a magnetic field in the iron core 122, the pole-pieces 129 and 130 of which produce a magnetic field in the space between the two anode plates 204 and 206 in a direction transverse to the path of electrons between the cathode 202 and the anode plates 204 and 206 thereby to control the electrons preferably to produce a glancing incidence of the electrons with respect to the anode plates 204 and 206. The magnet core 122 of iron or other suitable material serves to concentrate the magnetic field produced by the winding 259 and may also serve to modulate the radio frequency output oscillations in accordance with signals impressed on the signal source 64. The signal modulated voltages from the source 64 may be introduced through a separate or auxiliary winding 270 wound on the magnetic core 122 and connected by a circuit including conductors 250 and 252 and a condenser 254 with the signal source 64, thereby to provide a system of magnetic field modulation separately or in combination with plate modulation in connection with the two anode plates 204 and 206 which may be coupled with the signal source 64 by means of a circuit including the transformer 260. By suitably adjusting the variable condenser 254 and the variable transformer 260, the signal modulated voltages from the source 64 may be so adjusted in phase and magnitude as to provide straight line amplitude modulation at a point where substantially no frequency modulation occurs thereby to reduce distortion in the modulated oscillations.

While Figs. 7 and 9 show systems of magnetic field modulation combined with plate modulation on two anode plates 204 and 206, it will be understood that the system of magnetic field modulation may be combined similarly with other forms of plate modulation as, for example, the combination of magnetic field modulation with anode plate modulation in a magnetron tube having only a single anode plate (not shown); or the combination of magnetic field modulation with plate modulation upon one anode plate 102 of the plurality of anode plates 100 and 102 as shown in Fig. 6; or the combination of magnetic field modulation with plate modulation upon auxiliary plates as upon the auxiliary end plates 50 and 52 of Figs. 1 and 3, or as upon the auxiliary plates 104 and 106 as shown in Fig. 4. Also, in systems of combination plate and magnetic field modulation as illustrated herein, for example, the signal modulation voltages may originate from the same or common source and, in addition, may be so adjusted in phase and magnitude as to reduce signal distortion and also frequency modulation.

While in Figs. 1 to 7, the signal modulating voltages have been impressed upon the same winding that produces the magnetic field, it will be understood that the modulating voltages may be impressed upon a separate or auxiliary winding as shown in Fig. 9 to influence the field produced by the magnetic field producing winding and that such winding or windings may be of the air core type as shown in Figs. 1, 3, 6, and 7 or of the iron core type as shown in Figs. 4 and 9.

And, while the various modifications illustrated have been shown as adapted to be responsive particularly to telephonic signals, it will be understood that they may be modulated when modulation is desired, by telegraphic signals as by telegraph keying means or tone telegraphy systems.

Although this invention has been described and illustrated in relation to specific arrangements, it is to be understood that it is capable of application in other organizations and is, therefore, not to be limited to the particular embodiments disclosed but only by the scope of the appended claims and the state of the prior art.

What is claimed is:

1. Apparatus for generating signal-modulated oscillations including a space discharge device having a cathode, an anode disposed around said cathode and auxiliary electrode plate structure disposed adjacent the opposite ends of said cathode and anode, magnetic field producing means, a common source of signal currents, and modulating means responsive to said common source for simultaneously influencing said magnetic field and said auxiliary end plate structure and including reactance means for controlling the relative phase and magnitude of the signal currents supplied to said field producing means with respect to the signal currents supplied to said auxiliary end plate structure from said common source for modulating the amplitude of said oscillations in linear relation with respect to the amplitude of said signal currents whereby distortion in said modulated oscillations is reduced.

2. Apparatus for generating signal-modulated oscillations including a space discharge device having a cathode, an anode disposed around said cathode and auxiliary electrode plate structure disposed adjacent the opposite ends of said cathode and anode, magnetic field producing means, a common source of signal currents, and means simultaneously responsive to said common source of signal currents and including said magnetic field producing means and said auxiliary end plate structure for modulating the amplitude of said oscillations in linear relation with respect to the amplitude of said signal currents.

3. Apparatus for generating signal-modulated oscillations including a space discharge device having a cathode, anode structure and auxiliary plate structure disposed concentrically with respect to said cathode, magnetic field producing means, a common source of signal currents, and means simultaneously responsive to said common source of signal currents for applying said signal currents to said magnetic field producing means and said auxiliary plate structure for modulating said oscillations in accordance with said signal currents, and reactance means connected with said last-mentioned means for controlling the relative phase of the signal currents applied to said field producing means with respect to the signal currents applied to said auxiliary plate structure for modulating the amplitude of said oscillations in linear relation with respect to the amplitude of said signal currents of said source.

4. A magnetron oscillator comprising a space discharge device having an envelope, cathode and anode structure disposed within said envelope, means for producing magnetic and electrostatic fields with respect to said structure to cause said device to generate oscillations, auxiliary electrodes disposed at the opposite ends of said structure and means for applying negative potentials to said auxiliary electrodes of such negative values with respect to said cathode as to repel electrons emitted from said cathode and prevent destructive bombardment of said envelope by said electrons.

5. The combination in a high frequency signaling system of a space discharge device having

cathode and anode structure inclosed in an evacuated receptacle, means for causing said device to generate signal-modulated oscillations including an oscillatory circuit connected with said structure, means for producing a magnetic field in the space between said cathode and anode, a pair of auxiliary electrodes disposed at the opposite ends of said cathode and anode structure, a source of signal currents, means for applying signal-modulated potentials to said auxiliary electrodes in accordance with variations in said signal currents to correspondingly vary the high frequency oscillations in said oscillatory circuit and means for applying negative potentials to said auxiliary electrodes of such negative values with respect to said cathode as to repel electrons emitted from said cathode and prevent destructive bombardment of said envelope by said electrons.

6. In a high frequency oscillation generator, a space discharge device comprising a cathode, a plurality of anode plates oppositely disposed around said cathode, a plurality of auxiliary electrodes oppositely disposed around said cathode and disposed between said anode plates, means for producing a magnetic field between said plates, means including an output oscillatory circuit and a source of potential connected with said plates, a source of signal currents, and means including a circuit connecting said signal current source with said auxiliary electrodes for supplying signal modulated potentials to said auxiliary electrodes whereby the high frequency oscillations in said oscillatory circuit are varied in accordance with said signals.

7. Apparatus for generating high frequency oscillations including a space discharge device having cathode and anode structure, a plurality of auxiliary electrodes, means including magnetic means influencing said device, a tunable output circuit connected with said anode structure for generating oscillations, piezoelectric means, and means including a circuit separate from said output circuit operatively connecting said piezoelectric means with said plurality of auxiliary electrodes for stabilizing the frequency of said oscillations.

8. Apparatus for generating signal-modulated oscillations including a space discharge device having a pair of oppositely disposed electrodes and another pair of oppositely disposed auxiliary electrodes, a linear cathode disposed between said pairs of electrodes, means for producing a magnetic field substantially in the direction of the axis of said linear cathode, a tunable output circuit and a source of potential operatively connected with said first-mentioned pair of electrodes, piezoelectric means operatively connected with one pair of said pairs of electrodes for stabilizing the frequency of said oscillations, a source of signal currents, and means connecting said source with said magnetic field producing means and with at least one of said electrodes for modulating said oscillations in accordance with said signal currents, said connecting means including reactive means adjusting the phase and magnitude of said signal currents to modulate without distortion the amplitude of said oscillations in accordance with the amplitude of the signal currents in said source.

9. Apparatus for generating oscillations including a space discharge device having a cathode, anode structure disposed concentrically with respect to said cathode and auxiliary electrode structure disposed adjacent the opposite ends of

said cathode and anode structure, a tunable output circuit connected with said anode structure, means for producing a unidirectional magnetic field transverse to the direction of the electron path in the space between said cathode and anode structure, piezoelectric means connected with one of said structures for stabilizing the frequency of said oscillations, means for applying to said auxiliary electrode structure potentials which are negative with respect to said cathode, and means for applying signal potentials to said auxiliary electrode structure for modulating said oscillations in accordance with said signal potentials.

10. Apparatus for generating oscillations including a space discharge device having a cathode, anode structure and auxiliary electrode structure said anode and auxiliary electrode structure comprising curved plates disposed concentric with and equidistant from said cathode, a tunable output circuit connected with said anode structure, means for producing a unidirectional magnetic field transverse to the direction of the electron path in the space between said cathode and anode structure, piezoelectric means, means including a circuit separate from said output circuit connecting said piezoelectric means connected with said auxiliary electrode structure for stabilizing the frequency of said oscillations, and means for applying signal potentials to said anode structure for modulating said oscillations in accordance with said signal potentials.

11. Apparatus for generating oscillations including a space discharge device having a cathode, a plurality of anode plates and auxiliary electrode structure, an oscillatory circuit connected with said anode plates for generating oscillations, means for producing a magnetic field in the space between said cathode and anode plates, a source of constant potential, piezoelectric means connected with said auxiliary electrode structure for stabilizing the frequency of said oscillations, means for maintaining one of said anode plates at the potential of said source and for applying signal potentials to another of said anode plates for modulating said oscillations in accordance with said signal potentials.

12. Apparatus for generating oscillations including a space discharge device having a cathode, two pairs of oppositely disposed quarter cylindrical electrode plates surrounding and concentric with said cathode, means for producing a magnetic field between said cathode and electrode plates, means including an oscillatory circuit connected with one pair of said pairs of plates for generating oscillations, a piezoelectric device, and an auxiliary circuit separate from said oscillatory circuit and connecting said piezoelectric device with another pair of said pairs of plates for controlling the frequency of said oscillations, and means for applying signal potentials to at least one of said electrode plates for modulating said oscillations in accordance with said signal potentials.

13. Apparatus for generating oscillations including a space discharge device having a cathode, two pairs of oppositely disposed quarter cylindrical spaced electrodes surrounding said cathode, means for producing a magnetic field between said electrodes and said cathode, means for causing one pair of said pairs of electrodes to generate high frequency oscillations, and means for applying signal potentials to another pair of said pairs of electrodes to modulate said oscillations in accordance with said signal potentials.

14. Apparatus for generating oscillations in-

cluding a space discharge device having cathode and plate structure, means for producing a magnetic field influencing said structure, an oscillatory circuit connected with said structure, a
5 source of signal potentials, and means forming connecting paths for said source with said structure and with said magnetic field producing means, said connecting means including reac-

tance means for changing the relative phase of currents in one of said paths with respect to the other for modulating the amplitude of said oscillations in linear relation with respect to the amplitude of said signal potentials.

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