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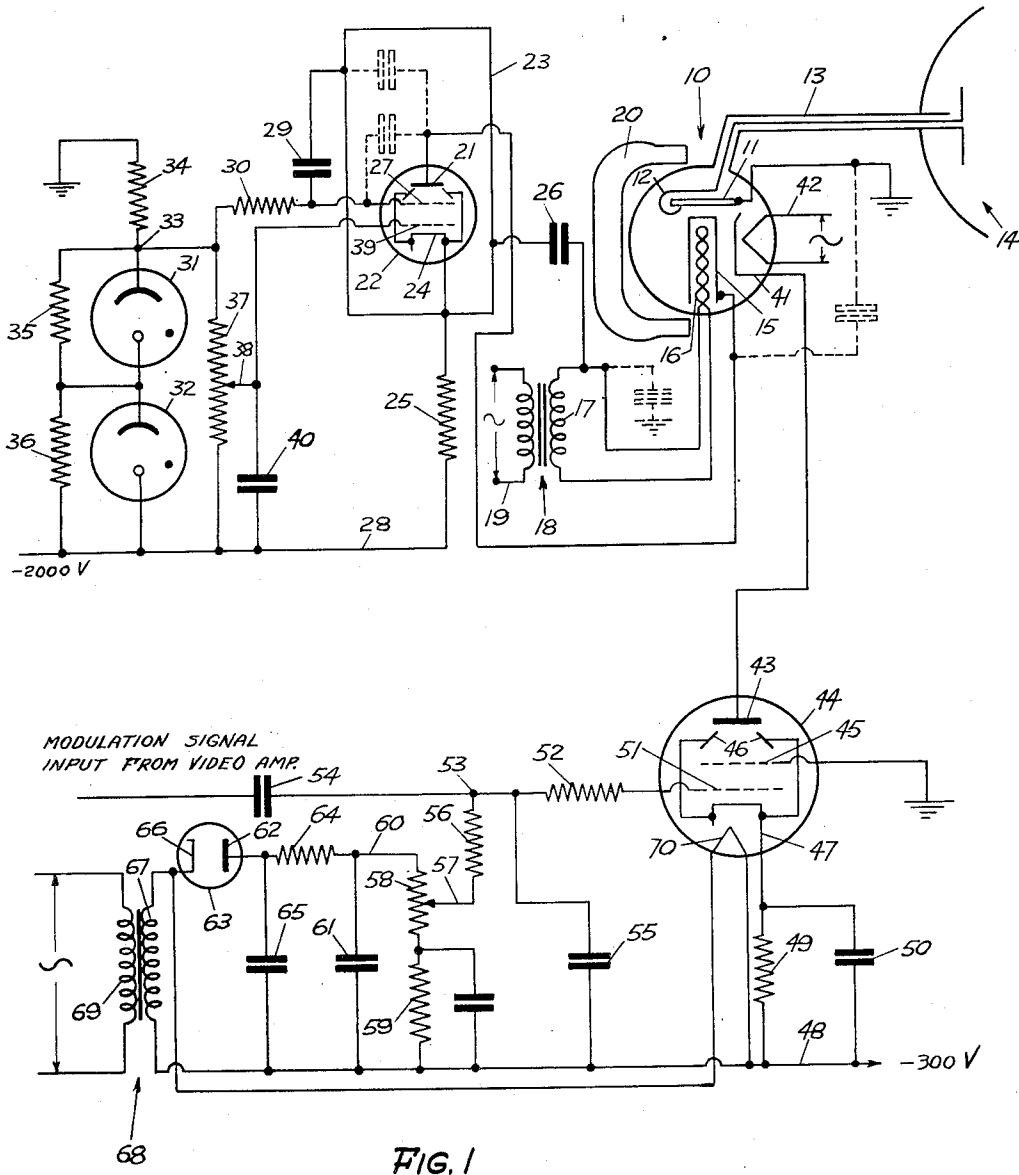
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2,774,941

COMMUNICATION SYSTEMS

Filed Nov. 14, 1952

2 Sheets-Sheet 1



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FIG. 2

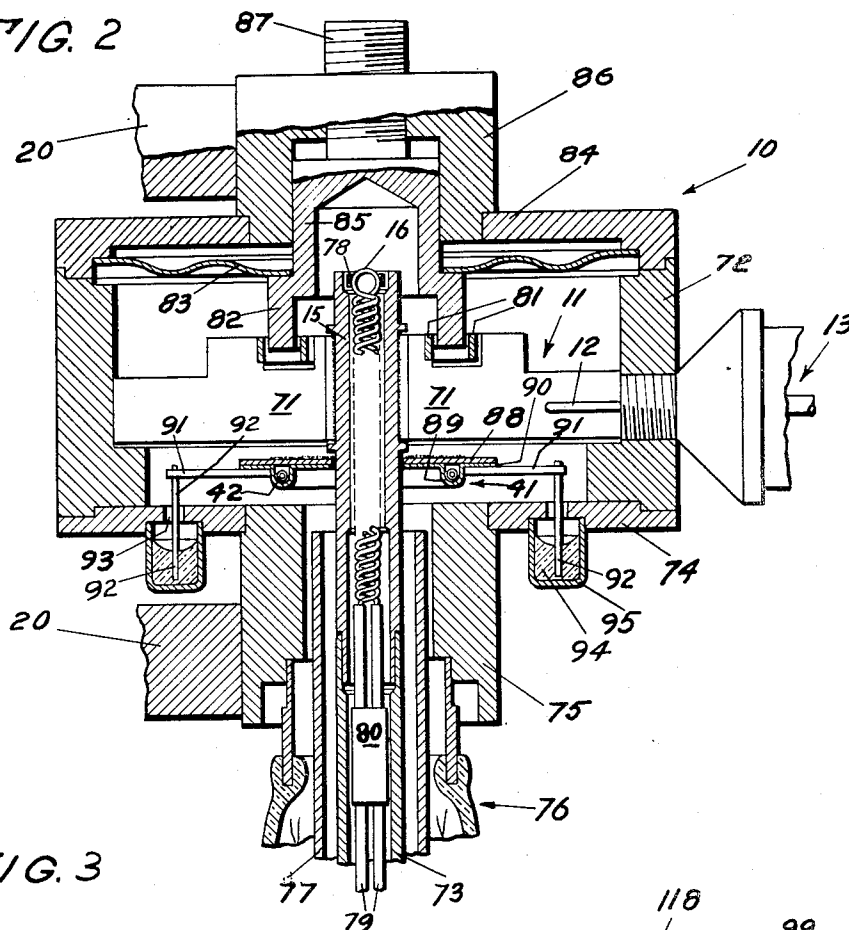
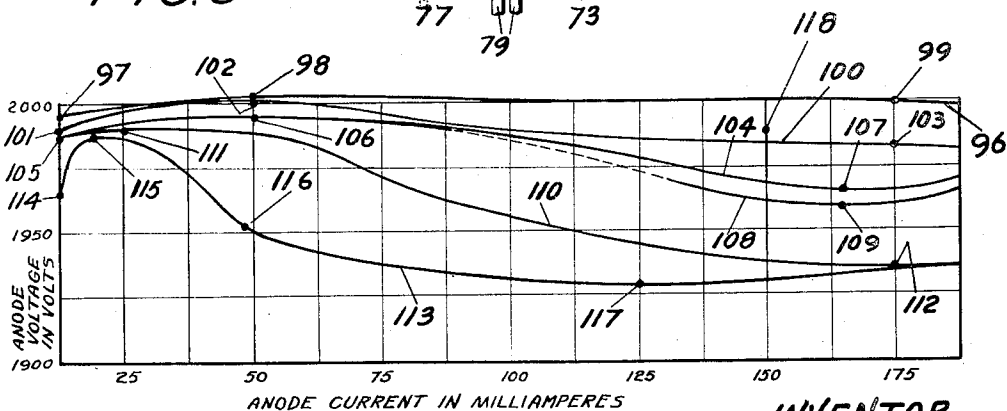


FIG. 3



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COMMUNICATION SYSTEMS

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This invention relates to communication intelligence modulation circuits and more particularly to circuits for utilizing electrically tunable magnetrons for modulation purposes.

Magnetrons have previously been developed in which the output frequency could be adjusted by injecting electrons into the resonator cavities of the magnetron. However, when these devices were used in the circuits, it was found that they produced undesired interfering modulation components on the output carrier in addition to the desired intelligence modulation components applied to the modulating circuit of the magnetron.

This invention discloses that the undesirable interference modulating components results in part from operating instability in the magnetron anode circuit which allows the magnetron a choice of operation at a plurality of different points on the magnetron anode-voltage anode-current curve. In effect, the magnetron would present a negative resistance load to the high voltage anode power supply. This invention discloses that the effective negative resistance region of the magnetron characteristic is of a type which may be termed "open circuit stable," which may be defined as being stable when driven by an open circuit or constant current generator.

This invention further discloses a specific constant current generator circuit for electrically tunable magnetrons. Specifically, the circuit comprises a grid-controlled electron discharge device in series with the magnetron anode supply and the magnetron with the control grid being returned to the cathode through a cathode load resistor through which flows the anode current of the magnetron and said device. The electron discharge device is surrounded by a metallic shield which is connected to the cathode so that substantially all the stray capacitances of the tube are returned to the cathode rather than to ground, resulting in a reduction of the effective stray capacitances by a factor substantially equal to one plus the gain of the electron discharge device. Reduction of the stray capacitances allows the anode supply circuit to act as a substantially constant generator over a relatively wide range of modulation frequencies, for example, up to ten megacycles.

This invention also discloses the use of a heater for the main cathode of the magnetron which is not directly connected to said main cathode. This allows further reduction of the stray capacitance of the magnetron anode supply circuit. In addition, the cathode heater is made in the form of a double helix, thereby reducing hum at the frequency of the heater supply in the modulation components.

Other and further objects and advantages of this invention will become apparent as the description thereof progresses, reference being had to the accompanying drawings, wherein:

Fig. 1 illustrates a circuit embodying the invention;

Fig. 2 illustrates a partially broken-away view of an

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electrical tunable magnetron of the type used in Fig. 1; and

Fig. 3 illustrates a graph operating characteristics of the magnetron illustrated in Fig. 2.

Referring now to Fig. 1, there is shown a magnetron illustrated diagrammatically at 10 comprising a main anode structure 11 which is connected to ground. An output coupling 12 is connected to anode 11 and feeds coaxial line 13, which, in turn, feeds an antenna 14. Magnetron 10 has a main cathode 15, which is heated by a double helically-wound heater 16 supplied from the secondary 17 of a low interwinding capacitance transformer 18, whose primary 19 is connected to a suitable source of low frequency alternating current. A suitable field is impressed across magnetron 10 by a permanent magnet 20, such that, when a suitable potential is applied to the cathode 15, magnetron 10 will oscillate at a frequency determined by the resonant frequency of the anode cavities.

The desired anode circuit potential is applied to the magnetron 10 by connecting the cathode 15 to the plate 21 of a beam power amplifier tube 22 positioned within a shielding container 23. Shielding container 23 is connected directly to the cathode 24 of tube 22 and to a negative high voltage bus 28, having a voltage, for example, on the order of minus 2000 volts, through a cathode load resistor 25. Shield 23 is also connected to one side of the secondary 17 of transformer 18 through a condenser 26 and to the screen grid 27 of tube 22 through a condenser 29. The screen grid 27 of tube 22, which may be, for example, a type 4D32 vacuum tube, is connected through a current-limiting resistor 30 and two voltage regulator tubes 31 and 32 in series to the negative high voltage bus 28. The junction 33, between current-limiting resistor 30 and voltage regulator tube 31, is connected to ground through a dropping resistor 34. The polarities of voltage regulator tubes 31 and 32 are so connected that the junction 33 is maintained positive with respect to the negative high voltage supply by combined voltage regulating drop of voltage regulator tubes 31 and 32 with the remainder of the negative high voltage supply being dropped across resistor 34. Voltage regulators 31 and 32 are shunted by resistors 35 and 36 in series whose junction is connected to the junction between voltage regulators 31 and 32, thereby insuring substantially stable operation of this voltage regulating system. Junction 33 is also connected to the negative high voltage bus 28 through a potentiometer 37 having an adjustable tap 38 which is connected to the control grid 39 of tube 22 and to the bus 28 through a signal by-pass condenser 40. Adjustment of tap 38 adjusts the current through tube 22 and, hence, the point of operation of magnetron 10 on its characteristic curves.

In order to vary the oscillating frequency of the magnetron 10, there is provided an electron source for directing electrons into the cavities of the magnetron anode. This electron source comprises a cathode 41 isolated from the cathode 15 and having a separate heater 42, which is connected to a suitable low frequency heater current supply. Cathode 41 is connected to the anode 43 of a modulation driver stage comprising a beam power amplifier tube 44, which may be, for example, a type 4D32 vacuum tube. The screen grid 45 of tube 44 is connected to ground. The beam-forming plates 46 of tube 44 are connected internally to the cathode 47 which is connected to a negative voltage bus 48 of, for example, minus 300 volts through a cathode bias resistor 49 bypassed by a condenser 50.

The grid 51 of tube 44 is connected through a parasitic suppressing resistor 52 to a junction point 53, which is connected through a D. C. blocking condenser 54 to

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a modulation signal input from a video amplifier not shown. Junction point 53 is connected through a condenser 55, which is part of a video amplifier compensation circuit, to the negative voltage bus 48. For example, if the anode supply for the magnetron 10 is designed with an upper limit on the order of ten megacycles, the by-pass condenser 55 should substantially entirely by-pass all frequencies above 10 megacycles to ground.

Junction 53 is also connected through a signal load resistor 56 to the movable tap 57 of a potentiometer 58, one side of which is connected through a resistor 59 to the negative voltage bus 48, and the other side of which is connected to a grid bias voltage source comprising a bus 60. Bus 60 is connected to bus 48 through a filter condenser 61 and to the plate 62 of a rectifying diode 63 through a filtering resistor 64. Plate 62 is also connected to the negative voltage bus 48 through a filter condenser 65. The cathode 66 of tube 63 is connected to the negative voltage bus 48 through the secondary winding 67 of a transformer 68 whose primary winding 69 is connected to a source of alternating current. If desired, the secondary winding 67 may also be connected to supply the heater 70 of the tube 44. It has been found that there is a certain amount of noise generated in the electronic tuning system of the magnetron 10. This may be minimized by adjusting the potentiometer tap 57 which adjusts the bias of the electronic tuning system, such that the tuning current bias of the magnetron 10 is relatively large.

Referring now to Fig. 2, there is shown the details of a magnetron which may be used for the magnetron 10 in Fig. 1. The anode structure 11 comprises a plurality of anode members 71 which extend inwardly from a metallic anode cylinder 72 comprising a portion of the envelope of the magnetron. The inner ends of anode member 71 define a cylindrical space in which is positioned the main cathode 15 of the magnetron. The main cathode 15 is supported at its lower end by a lead-in support member 73 which extends upwardly through an opening in a lower end plate 74, which is sealed to the anode cylinder 72 and through a lower magnetic pole piece 75 positioned in the aperture in plate 74. The support member 73 is hermetically sealed to the pole piece 75 through an insulated seal partially shown at 76.

Egress of energy generated in the magnetron through the apertures adjacent the cathode lead-in support 73 is prevented by choke member partially shown at 77 surrounding lead-in member 73 and inside pole piece 75 spaced therefrom. Positioned within cathode 15 is a heater structure 16 comprising a double helical winding connected together at the upper end of cathode 15 and insulatingly supported at the upper end thereof by an insulating member 78. Heater 16 is covered with insulating material, such as alundum, to prevent shorting of the heater 16 to the cathode 15, as well as shorting between the turns of the heater. The ends of the heater at the lower end of the cathode 15 are connected to separate lead-in members 79 which extend downwardly through cathode support 73 spaced therefrom by an insulator 80 and extend out beyond the end of cathode support 73 through insulating seals not shown. An output coupling loop 12 is connected to the anode structure 11 and feeds an output coaxial line 13. Anode members 71 are alternately connected on their upper edges adjacent their inner ends by a pair of conductive straps 81 according to well-known practice.

Means are also provided for mechanically tuning the magnetron in order to adjust the center frequency of the device. The tuning means comprises a cylindrical member 82 adapted to be inserted between the straps 81, thereby varying the capacitance at the inner ends of the anode member 71, and as a result varying the resonant frequency of the magnetron anode cavities. A flexible

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hermetic seal is provided between the tuning cylinder 82 and the anode by means of a diaphragm 83 sealed at its inner edge to the cylinder 82 and at its outer edge to an upper metallic cover plate 84, which, in turn, is sealed to the anode cylinder 72. Cylinder 82 is attached to a cylindrical support portion 85, which extends up through and slidably engages upper magnetic pole piece 86, which is positioned in an aperture in upper end plate 84. A threaded stud portion 87 extends outwardly beyond the upper end of pole piece 86 and engages mechanical means, not shown for adjusting the position of tuning cylinder 82. The permanent magnet 20 engages the pole pieces 86 and 75, thereby creating the desired magnetic field in the interaction space between the main cathode 15 and the tips of the anode members 71.

The electronic tuning cathode 41 comprises a flat disk 88 surrounding the main cathode 15 spaced therefrom below the anode members 71, the upper surface of disk 88 being coated with electron-emissive material. Positioned below the disk 88 is the heater coil 42 for the cathode 41, said heater coil being insulatingly supported in an annular recess 89 struck downwardly into a plate 90 positioned below disk 89 and rigidly attached thereto as by welding. The cathode 41 is supported by means of straps 91 connected between plate 90 and support pins 92 which extend downwardly through apertures 93 in the lower end plate 74 outside the magnetic pole piece 75. Support pins 92 are set in insulating members 94 positioned in metallic cups 95, which, in turn, are sealed to recesses in the lower end plate 74 surrounding the apertures 93. The lead-outs for the heater 42 and the cathode 41 are provided by substituting suitable insulating seals provided with lead-in members for the support pins 92 and ceramic members 94 in the metal cups 95. These details, however, are not shown in the drawing.

Referring now to Fig. 3, there is shown a graph illustrating operating characteristics of the magnetron illustrated in Fig. 2. Along the axis of ordinates is plotted the anode voltage, applied between the anode 11 and main cathode 15, in volts, and, along the axis of abscissae is the anode current in milliamperes. Curve 96 represents a tuning current from cathode 41 of substantially 150 milliamperes and moves gradually from an anode voltage on the order of 1995 volts at an anode current of 12½ milliamperes, as shown by point 97, to a maximum anode voltage of approximately 2005 volts at an anode current in the region of fifty milliamperes, as shown by point 98, and then decreases gradually to an anode voltage slightly less than 2000 at an anode current of 175 milliamperes, as shown by point 99.

Curve 100 is for a tuner current of 100 milliamperes and moves gradually from an anode voltage of around 1990 volts at 12½ milliamperes of anode current, as shown by point 101, to a maximum of slightly more than 2000 volts at an anode current in the region of fifty milliamperes, as shown by point 102, and then decreases gradually to an anode voltage of approximately 1980 volts at an anode current of 175 milliamperes, as shown by point 103.

Curve 104 corresponds to a tuner current of seventy-five milliamperes, and rises gradually from an anode voltage of slightly greater than 1985 volts at an anode current of 12½ milliamperes, as shown by point 105 on the curve to a maximum of approximately 1990 volts at an anode current of fifty milliamperes, as shown by point 106 on the curve, after which it gradually decreases to a minimum voltage of approximately 1965 volts at an anode current of 165 milliamperes, as shown by point 107 on the curve, after which the voltage again rises gradually with increasing anode current.

Curve 108 corresponds to a tuner current of fifty milliamperes, and substantially coincides with curve 107 from points 105 to 106, after which it drops somewhat faster than curve 107 and reaches a minimum voltage of ap-

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proximately 1960 volts at an anode current of 160 milliamperes, as indicated by point 109 on the curve, after which the anode voltage gradually rises with increasing anode current.

Curve 110 corresponds to a tuner current of twenty-five milliamperes and substantially coincides with curves 107 and 108 at point 105. However, curve 110 reaches a maximum anode voltage at an anode current of around twenty-five milliamperes, as shown by point 111, said anode voltage being only slightly greater than the anode voltage at point 105. Thereafter curve 110 drops gradually in anode voltage with increasing anode current until it reaches a value of approximately 1935 volts at an anode current of 175 milliamperes, as indicated by point 112 on the curve.

Curve 113 corresponds to zero tuner current and has a value of approximately 1960 volts at an anode current of 12½ milliamperes, as indicated by point 114 on the curve, and rises to a maximum voltage of approximately 1985 volts at an anode current of around fifteen milliamperes, as shown by point 115 on the curve. It then drops relatively sharply to an anode voltage of approximately 1950 volts at an anode current of forty-five milliamperes, as indicated by point 116 on the curve. Curve 113 then drops gradually with increasing anode current until it reaches a minimum of approximately 1930 volts at an anode current of approximately 125 milliamperes, as shown by point 117, after which it rises gradually in anode voltage with an increase in anode current.

From the curves illustrated in Fig. 3, it may be seen that over a part of the range of anode voltages and currents, the magnetron exhibits a negative resistance characteristic; that is, the anode voltage decreases with increasing anode current. Thus, the device is susceptible of producing spurious and unwanted oscillations if the device is fed from a substantially constant voltage source. If, however, the device is fed from a substantially constant current source which will supply any set current, for example, 100 milliamperes independently of anode voltage, the anode circuit of the magnetron will be prevented from generating spurious signals which effectively modulate the magnetron.

Good operating results are obtained when the anode supply circuit and the modulating circuit are adjusted to produce an anode current on the order of 150 milliamperes and a tuner bias current on the order of 120 milliamperes, as shown by point 118 on the graph illustrated in Fig. 3.

This completes the description of the species of the invention illustrated herein. However, many modifications thereof will be apparent to persons skilled in the art without departing from the spirit and scope of this inven-

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tion. For example, the magnetron need not necessarily be of the type shown in Fig. 2, but rather any electrically-tuned magnetron may be used. The modulating circuit illustrated may be used for modulating the device with signals other than video; for example, narrow band signals and the output of the magnetron need not necessarily be fed directly to the antenna, but may be fed to other suitable amplifying devices or to any other desired load. Accordingly, it is desired that the invention be not limited to the particular details of the embodiment of the invention described herein, except as defined by the appended claims.

What is claimed is:

1. An electron discharge system comprising a magnetron, said magnetron having a main cathode, said cathode having a heater substantially insulated therefrom and a power supply for said magnetron, said power supply comprising a degenerative feedback amplifier stage comprising a grid-controlled electron discharge device having a load impedance in the cathode circuit thereof, and the main cathode of said magnetron in the anode circuit of said device, said device being substantially surrounded by a conductive shield, said shield being electrically connected to the cathode of said device.
2. An electron discharge system comprising a magnetron, said magnetron having a main cathode, said cathode having a double helically-wound heater substantially insulated therefrom, means for electronically frequency modulating said magnetron and a power supply for said magnetron, said supply exhibiting a substantially constant output current characteristic over the desired range of modulating frequencies, said power supply comprising a degenerative feedback amplifier stage comprising a grid-controlled electron discharge device having a load impedance in the cathode circuit thereof, and the main cathode of said magnetron in the anode circuit of said device, said device being substantially surrounded by a conductive shield, said shield being electrically connected to the cathode of said device.

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