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TRANSITION FROM BIFILAR HELIX TO WAVEGUIDE FOR BACKWARD WAVE OSCILLATOR

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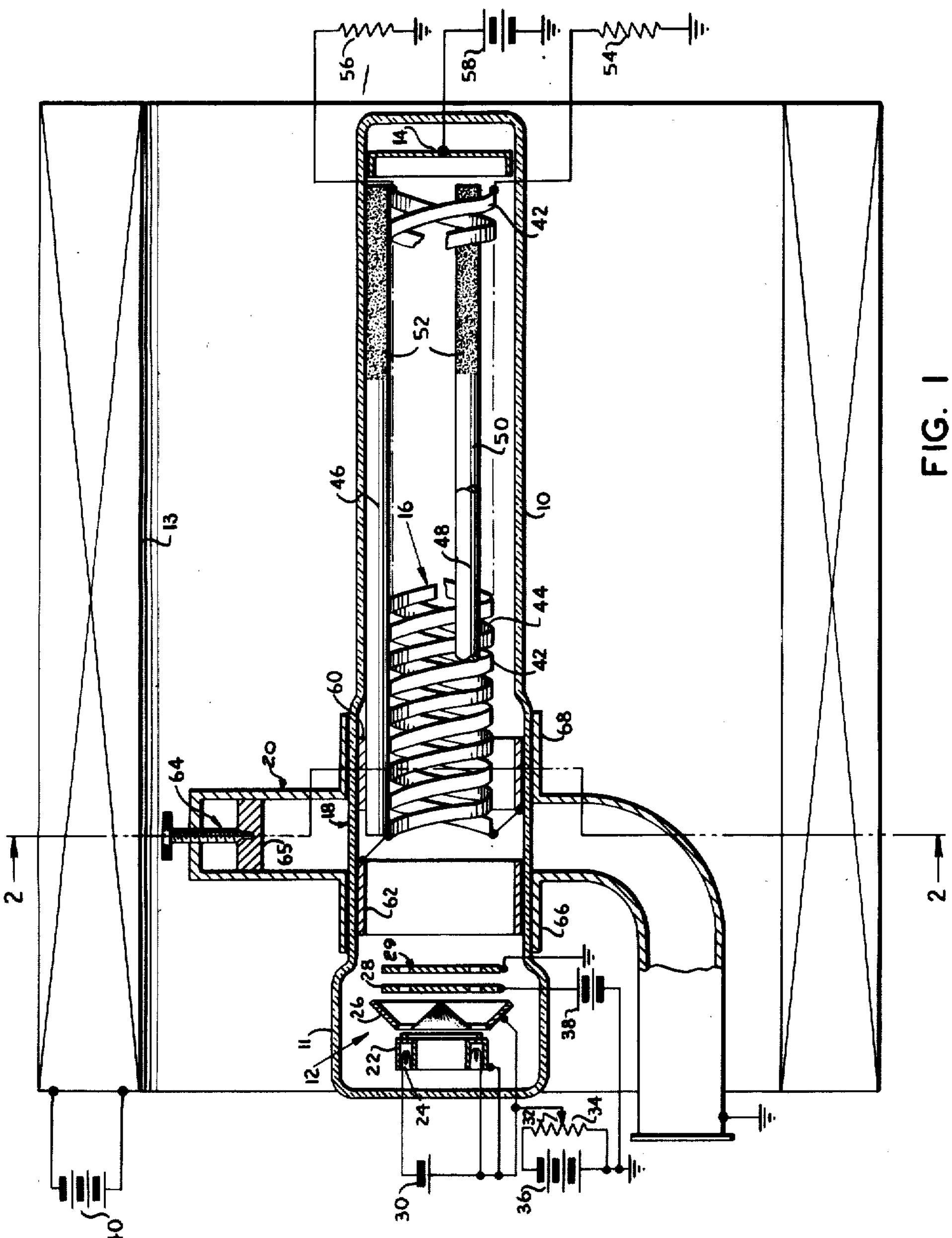

FIG. 1

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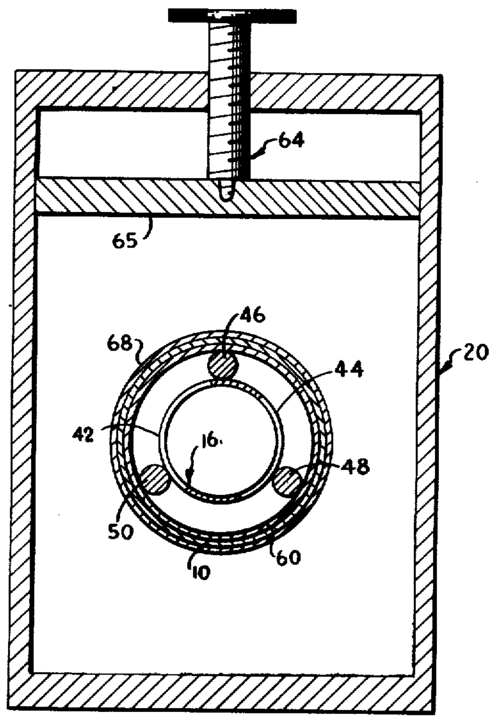

FIG. 2

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TRANSITION FROM BIFILAR HELIX TO WAVE-GUIDE FOR BACKWARD WAVE OSCILLATOR

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6 Claims. (Cl. 315—3.6)

This invention relates to microwave oscillators and more particularly to a backward wave oscillator employing an enlarged bifilar helix and incorporating structure for providing a transition between the bifilar helix and a waveguide over a broad range of frequencies.

As is generally known a backward-wave oscillator is a device wherein an electron stream is directed through a slow-wave structure at a velocity and in a manner to amplify an electromagnetic wave the energy of which is propagated by the structure in a direction opposite to that of the electron stream. An eletromagnetic wave of this type is typically designated as a "backward wave." Bifilar helices are particularly adaptable for use as the slow-wave structure in this type of oscillator because of the high impedance they present to backward waves. This structure, however, presents the problem of providing a good tansition from the bifilar helix to a waveguide or other output structure over the frequency range of the oscillator. In the event that there is a poor transition to the output structure from the bifilar helix, it is generally realized that a large standing wave will result which causes variations in amplitude and "frequency pulling" in the output signal as the oscillator is tuned throughout its frequency range. Frequency pulling and amplitude variations are caused by reflections occuring at an extremity of the helix and having sufficient magnitude to produce internal feedback.

In accordance with the present invention a backward-wave oscillator employing a bifilar helix is provided having an improved transition therefrom to an output waveguide section with minimized variations in amplitude and frequency pulling throughout the operating frequency range of the oscillator. The apparatus providing the transition comprises two similar ferrules, each of which has an inside diameter substantially larger than the helix. These ferrules are disposed symmetrically with respect to the output extremity of the helix concentrically about its longitudinal axis. Each ferrule is connected to a different helix at diametrically opposite points. An output waveguide section symmetrically encloses the two ferrules so that the gap therebetween appears midway between the broad sides of the waveguide and at a distance of approxi-mately one-quarter of a guide wavelength from a virtual or actual shorting plane within the waveguide. In operation, the electromagnetic wave propagated by the bifilar helix produces an electric field across the gap between the ferrules which in turn excites an output signal in the waveguide.

It is therefore an object of this invention to provide an improved backward-wave oscillator capable of producing an output signal with minimum amplitude variation and frequency pulling while being tuned over a wide range of frequencies.

Another object of this invention is to provide a backward-wave oscillator employing a bifilar helix with an improved transition structure to match the impedance of the helix to that of a waveguide.

Still another object of this invention is to provide a

simple structure capable of effecting a transition between a bifilar helix and a waveguide over a broad range of frequencies.

The novel features which are believed to be characteristic of the invention both as to its organization and method of operation, together with further objects and advantages thereof, will be better understood from the following description considered in connection with the accompanying drawing in which an embodiment of the invention is illustrated by way of example. It is to be expressly understood, however, that the drawing is for the purpose of illustration and description only, and is not intended as a definition of the limits of the invention.

Fig. 1 is a cross-sectional view in partial elevation of an embodiment of the present invention together with associated circuitry; and

Fig. 2 is a section along line 2—2 of Fig. 1.

Referring now to the drawing, Figs. 1 and 2 show an embodiment of the present invention comprising an elongated cylindrical envelope **10** having an enlarged portion **11** at the left extremity as viewed in the drawing. Enlarged portion **11** houses an electron gun **12** for producing a hollow cylindrical electron stream. This electron stream is directed along a path that runs parallel with the longitudinal axis of envelope **10** by means of a solenoid **13**. A collector electrode **14** is disposed at the extremity of envelope **10** farthest from electron gun **12** to intercept and collect the electron stream. Disposed contiguously about the path of the electron stream intermediate the electron gun **12** and collector electrode **14** is a bifilar helix **16**. In accordance with the present invention a transition device **18** for matching the impedance of bifilar helix **16** to a rectangular output waveguide section **20** is disposed about the extremity of bifilar helix **16** nearest the electron gun **12**.

More particularly, the electron gun **12** comprises an annular cathode **22** with a heater **24**, a focusing electrode **26**, and accelerating electrodes **28** and **29**, the electrodes **26**, **28**, and **29** being provided with apertures in register with the electron emitting annular surface of cathode **22** to allow passage therethrough of the hollow cylindrical electron stream. Heater **24** is connected across a source of potential, such as a battery **30**, one terminal of which may be connected to cathode **22** as shown. The electrode **26** provides an inner and an outer surface of revolution adjacent to and about the electron-emitting surface of cathode **22**, as shown in the figure, to provide focusing of the electron stream. Cathode **22** and focusing electrode **26** are connected together and are, in turn, connected to an adjustable tap **32** of a potentiometer **34**. Potentiometer **34** is connected across a source of potential **36**, the positive terminal of which is connected to ground. The magnitude of the potential provided by the source **36** may be of the order of 5000 volts. Accelerating anode **28** is disposed in a plane normal to the longitudinal axis of envelope **10** to the right of focusing electrode **26** as viewed in the drawing. Anode **28** is maintained at a substantially fixed potential of the order of 200 volts positive with respect to ground by means of a connection therefrom to the positive terminal of a battery **38**, the negative terminal of which is referenced to ground. Anode **29**, on the other hand, is disposed intermediate the anode **28** and bifilar helix **16** in a plane normal to the longitudinal axis thereof and is maintained at ground potential by means of an appropriate connection thereto.

The solenoid **13** is positioned concentrically about the envelope **10** and is coextensive with the active length of the tube. An appropriate direct current is made to flow through the solenoid **13** by means of connections across a battery **40** to produce an axial magnetic field of the order of 600 gauss through the tube. The purpose of the magnetic field is to keep the electron stream constrained in its path from the electron gun **12** to the collector **14**. Also, inasmuch as a bifilar helix is employed as the slow-wave structure in the present invention, it is apparent that electrostatic focusing may be used in lieu of the magnetic field.

The bifilar helix **16**, disposed about the path of the electron stream may have a circumference that is either large or small in comparison to a free space wavelength at the frequency of operation of the device such as, for example, 0.6 or 0.15 wavelength, respectively. Helices **42** and **44** constitute the bifilar helix **16**. These helices **42**, **44** have equal pitches and diameters and may be made of a material such as tungsten or molybdenum, the main prerequisite being that they retain their form, especially with respect to pitch and diameter. Also, the inner diameter of the hollow electron stream should be from 0.2 to 0.95 the inner diameter of the bifilar helix **16** in order that the electron stream may flow in the electric field of the wave propagated by the structure.

Bifilar helix **16** is maintained in position by three ceramic rods **46**, **48** and **50** which have a length equal to that of the helix **16** and may, for example, be glazed at equal intervals about the outer periphery of helices **42**, **44**. Resistive coatings **52** are applied to the ceramic rods **46**, **48**, **50** coextensive with the last several turns of helices **42**, **44** farthest from the electron gun **12** to provide a termination for waves reflected from the output circuit of the tube. Resistive coatings **52** may, for example, be provided by an aqueous suspension of graphite generally known as "Aquadag." Helices **42**, **44** commence and end at diametrically opposite points of the bifilar helix **16** and are maintained at ground potential during operation of the device. This may be accomplished by connections from helices **42**, **44** through resistors **54**, **56** respectively, to ground. Also, the collector electrode **14** is maintained at a potential of the order of 200 volts positive with respect to ground by means of a connection therefrom to the positive terminal of a battery **58** which is, in turn, referenced to ground.

As previously stated, the transition device **18** matches the impedance of the bifilar helix **16** to the output waveguide section **20**. Transition device **18** comprises matching ferrules **60**, **62** which are composed of non-magnetic material and have a length equal to several turns of the bifilar helix **16** which may, for example, be of the order of 3/16 a free space wavelength at the mid-operating frequency of the device. The inside diameter of ferrules **60**, **62** is of sufficient magnitude to enable the bifilar helix **16** to propagate a backward wave through the ferrules **60**, **62** disposed concentrically about the helix **16** with little or no disturbance, i. e., without additional attenuation or reflection of the wave. Normally this would require that the inside diameter of the ferrules **60**, **62** be of the order of 0.25 inch greater than the outside diameter of the bifilar helix **16**. Structurally, the diameter of ceramic rods **46**, **48**, **50** are made equal to one-one half of this difference, i. e., 0.125 inch, so as to function as "spacers" for the helix when a ferrule is slipped over the outer periphery, as shown in Fig. 2.

The ferrules **60**, **62** are disposed concentrically about the longitudinal axis of the bifilar helix **16** with their adjacent ends spaced equidistant from the extremity thereof nearest electron gun **12** thus leaving a gap between the femrrules **60**, **62**, as shown in Fig. 1. This gap may vary from 0.01 to 0.15 a free space wavelength at the mid-frequency of operation and is preferably of the order of 0.1 free space wavelength. Ferrules **60**, **62** are connected, respectively, to helices **42**, **44** at diametrically opposite points of the bifilar helix **16** at the extremity thereof nearest electron gun **12**. The output waveguide section **20** is disposed symmetrically about the gap between ferrules **60** and **62** in a manner such that the electric field of its dominant transverse electric mode is parallel to the longitudinal axis of the helix **16**.

An adjustable shorting member **64** is provided, as shown in Figs. 1 and 2, to permit the distance from the shorted termination **65** of waveguide section **20** to the gap between ferrules **60** and **62** to be adjusted for maximum power transfer. Also, in order to prevent energy leakage from the waveguide, sleeves **66** and **68** extend from the apertures in the sides of the waveguide contiguously along the glass envelope **10**, as shown in the figures. The coextensive distance between ferrule **62** and sleeve **66**, and ferrule **60** and sleeve **68** is adjusted to produce a virtual shorting plane at the inner surface of the waveguide section **20**. This distance would depend on the radius of the apertures in the waveguide and the relative dielectric constant of the glass envelope **10** and would normally be of the order of 1/8 of the free-space wavelength corresponding to the frequency of operation of the device.

In its operation, the electron stream from the electron gun **12** would generate a backward wave on the bifilar helix **16**. At diametrically opposite points along the helix **16**, this wave is 180° out-of-phase. Thus the matching ferrules **60** and **62** are energized with electric fields that are 180° out-of-phase. These electric fields appear across the gap between ferrules **60**, **62** and, in turn, launch a wave in the output waveguide section **20**. The comparatively large diameter of the ferrules **60**, **62** contributes towards the broad-band characteristics of the impedance match thus provided between the bifilar helix **16** and the waveguide section **20**.

What is claimed is:

1. A backward wave oscillator comprising means for producing an electron stream, means for directing said electron stream along a predetermined path, a bifilar helix disposed contiguously along said predetermined path, whereby said electron stream generates a backward wave on said helix, first and second matching ferrules having an inside diameter greater than the diameter of said helix disposed concentrically about the longitudinal axis of said helix with the adjacent ends thereof on each side of the extremity of said bifilar helix first entered by said electron stream, said first and second matching ferrules being connected, respectively, to diametrically opposite points of said bifilar helix at said extremity, and a waveguide output structure disposed symmetrically about said first and second matching ferrules, whereby said ferrules provide a transition between said bifilar helix and said waveguide output structure.

2. The backward wave oscillator as defined in claim 1 including additional means for providing a shorting plane transversely across said waveguide at a distance equal to

$$\frac{2n-1}{4}$$

guide wavelengths at the frequency of said backward wave from the longitudinal axis of said bifilar helix, wherein n is a positive integer.

3. A backward wave oscillator comprising a bifilar helix including first and second helices commencing at points on the circumference of said bifilar helix diametrically opposite each other; means for producing a hollow cylindrical electron stream having a diameter less than the inside diameter of said bifilar helix; means for directing said electron stream concentrically through said bifilar helix to generate a backward wave on said helix; first and second matching ferrules having an inside diameter greater than the diameter of said bifilar helix disposed concentrically about the longitudinal axis thereof, the adjacent ends of said ferrules being disposed on opposite sides of the commencement of said bifilar helix and connected, respectively, to said diametrically opposite points thereof; and a waveguide output structure disposed symmetrically about said first and second matching ferrules, whereby said ferrules provide a transition for said backward wave from said bifilar helix to said waveguide output structure.

4. The backward wave oscillator as defined in claim 3 wherein the inside diameter of said first and second ferrules is at least 1.1 times the outside diameter of said bifilar helix.

5. A transition structure between a bifilar helix and a rectangular waveguide comprising: a bifilar helix capable of propogating an electromagnetic wave, said bifilar helix including first and second helices commencing at points on the circumference thereof diametrically opposite each other; first and second matching ferrules having an inside diameter greater than the diameter of said bifilar helix disposed concentrically about the longitudinal axis thereof, the adjacent ends of said ferrules being disposed on opposite sides of the commencement of said bifilar helix and connected, respectively, to said diametrically opposite points thereof; a rectangular waveguide disposed symmetrically about the gap between the adjacent ends of said matching ferrules, the longitudinal axis of said bifilar helix being normal to the broad sides of said waveguide; and means for providing a transverse shorting plane across said waveguide at a distance equal to

$$\frac{2n-1}{4}$$

guide wavelength at the frequency of said wave, wherein n is a positive integer.

6. The transition structure as defined in claim 5 wherein the dimension of said gap between the adjacent ends of said matching ferrules is from 0.01 to 0.15 a free space wavelength at the mid-frequency of operation of the device.

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