Feb. 25, 1958 D. C. ROGERS ET AL 2,824,996

TRAVELLING WAVE TUBES

Filed Aug. 2, 1954

FIG. 1.

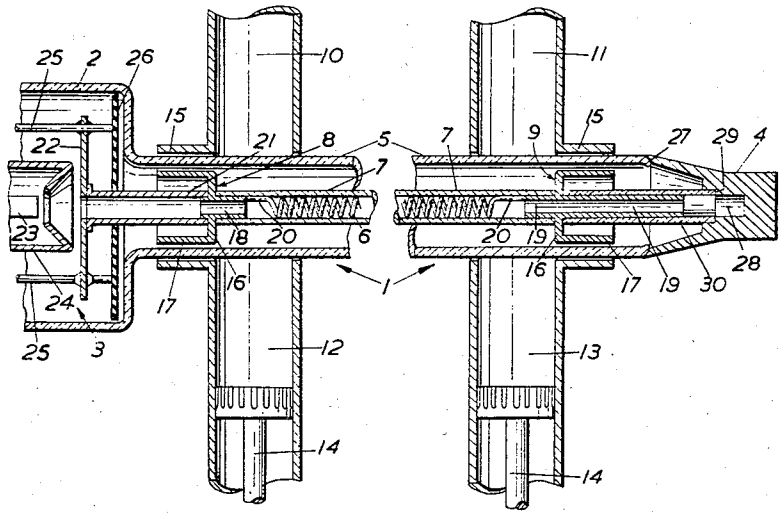
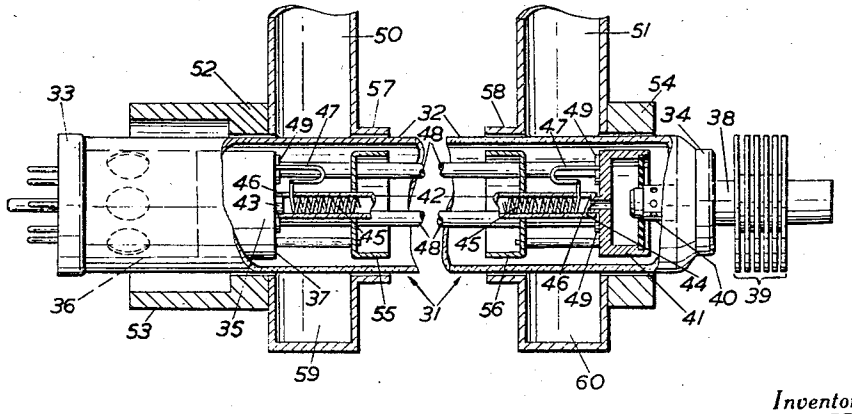


FIG. 2.



Inventors
D. C. ROGERS
P. F. C. BURKE
By R. P. Morris
Attorney

United States Patent Office 2,824,996
Patented Feb. 25, 1958

2,824,996

TRAVELLING WAVE TUBES

Douglas Cecil Rogers and Peter Francis Conway Burke, London, England, assignors to International Standard Electric Corporation, New York, N. Y.

Application August 2, 1954, Serial No. 447,173

Claims priority, application Great Britain October 14, 1953

5 Claims. (Cl. 315—3.5)

The present invention relates to travelling wave tubes.

In a travelling wave tube a beam of electrons is caused to interact with electromagnetic waves guided by a waveguide structure in such manner that a component of the waves travels along the electron beam path with a phase velocity approximately the same as that of the electrons. In the kind of tube most commonly used today the aforementioned waveguide structure is provided by a conductor formed into a helix. The travelling wave tube is most commonly used as a broad band amplifier but it is also capable of use as an oscillator or as a frequency changing device, or, indeed, in a number of ways in circuits analogous to those for which, at lower frequencies, triode and multi-grid thermionic valves are used. In association with the helix of a travelling wave tube, therefore, there must be at least an output wave coupling and, for most applications, both input and output connections. For this purpose the travelling wave tube usually projects through a rectangular hollow waveguide or through a cavity built out from a coaxial transmission line; in the present specification such a built-out transmission line is considered to be included in the term "hollow waveguide." While it is desired that electromagnetic waves may pass from the input waveguide to the helix or from the helix to the output waveguide, means have to be provided for preventing escape around the outside of the travelling wave tube of electromagnetic waves from the apertures in the waveguide walls through which the tube projects. The apparatus, therefore, includes a waveguide choke formed by a cylindrical flange projecting from the wall of the waveguide around the travelling wave tube in the direction opposite to the helix, and, inside the tube envelope, a corresponding inner sleeve member, coaxial with the cylindrical flange, thus providing, during operation, capacitative coupling between the waveguide or cavity wall and the internal sleeve member. The two choke members are usually a quarter wavelength long at the mean operating frequency, but, provided the characteristic impedance of the coaxial line formed between the inner and outer choke members is low, the exact length is unimportant.

The helix must be accurately dimensioned and must be adequately supported in the travelling wave tube so that it shall not intercept the electron beam current. Although the envelope of the travelling wave tube may itself provide the means of supporting and aligning the helix, it is generally preferred to use independent supporting means, such, for example, as glass rods arranged longitudinally about the exterior of the helix, and resting against the inner wall of the glass envelope. In one known type of travelling wave tube these glass rods are themselves seated in appropriate recesses in the internal waveguide choke members.

According to the present invention there is provided a travelling wave tube of the kind in which during operation a beam of electrons is projected along a waveguide structure in the form of a helix coupled by means including a waveguide choke to a hollow waveguide and interchanges energy with electromagnetic waves propagated along the said helix with a phase velocity approximately that of the said electrons, the said travelling wave tube comprising an electron gun structure, an electron collector electrode and a tube of insulating material supporting the said helix within an outer envelope and mounted at each end upon a sleeve member, at least one of which forms part of a said waveguide choke, the said sleeve member at the electron gun end of the tube being mounted upon or forming part of the said electron gun structure.

The invention will now be described with reference to the accompanying drawings, in which:

Fig. 1 shows diagrammatically the essential parts of a travelling wave tube according to the invention and associated waveguide apparatus with which the present invention is concerned; and

Fig. 2 shows a similar view of another embodiment of the invention.

In Fig. 1, which, primarily because of the very different thickness of material involved, the various parts are not shown necessarily to scale, a travelling wave tube, of which only the ends are shown, is indicated at 1 and comprises, at one end, an envelope bulb 2, housing an electron gun 3, and at the other end a collector electrode 4 sealed to the end of an envelope portion 5 of smaller diameter and considerably longer than the bulb portion 2. The envelope portion 5 surrounds a wire helix 6 supported within a tube of insulated material 7 which is mounted at either end upon respective sleeve members 8 and 9. To provide atenuation in asscciation with the helix waveguide structure, some lossy material can be painted or evaporated on the inside of tube 7, or, if the tube is sufficiently thin, on the outside. The envelope portion 5 is shown projecting through input and output hollow waveguides 10 and 11, respectively, which carry extensions 12 and 13 shown fitted with adjustable pistons 14 for improving the impedance match between the respective waveguides and the helix. Each of the waveguides is provided with a cylindrical flange 15 surrounding the travelling wave tube and projecting away from the helix. These flanges form, with the respective sleeves 8 and 9, waveguide chokes preventing escape of electromagnetic wave energy towards the electron gun and towards the collector electrode respectively. In the form shown in Fig. 1 each of the sleeve members 8 and 9 is formed by a disc portion 16 integral with a cylindrical skirt portion 17; member 8 carries a central tubular boss 18 projecting to either side of the disc portion 16 and member 9 a metallic tube 19 projecting considerably to the rear of the skirt and projecting in front of the disc portion 16 similarly to boss 18. The boss 18 and front projection of tube 19 are connected by straight lengths of wire 20 to the respective ends of the helix 6 to form antenna probes for coupling between the helix and the respective waveguide. For supporting the sleeve member 8 and providing electrical connection to the helix, a metal tube 21 is secured at one end to the final anode 22 of the electron gun 3, and fits snugly at its other end over the rear portion of the boss 18. Besides the anode 21 the electron gun 3 comprises a cathode 23 surrounded by a focusing cylinder 24, the electrodes being supported by means such as support rods 25 to respective insulating washers, the end one of which is shown at 26. The tube 21 can thus be secured, if desired, to the insulator 26 instead of to the anode 22; an independent connection for the helix can then be provided.

At the other end of the tube the electron collector electrode 4, which is represented as sealed to the envelope portion 5 by a feather-edged portion 27, encloses a gen-

erally cylindrical cavity 28 in which the electrons of the beam are collected. The wall of cavity 28 includes a step, indicated at 29, against which is seated a tube of insulating material 30 closely surrounding the rearward projection of tube 19. The tube 30 thus supports the output end of the helix and sleeve assembly. The provision, in sleeve member 9, of the tube 19 in place of the shorter boss 18 of sleeve member 8 prevents the collection of charges on the inner wall of the tube 30 which would, otherwise directly surround the electron beam.

It will be appreciated that, in the construction of Fig. 1, the electron gun structure, the helix and its supporting tube mounted upon the sleeve members 8 and 9, together with the sleeve support tubes 21 and 30, can be constructed as a rigid unitary assembly which may be inserted at a convenient stage of manufacture into the travelling wave tube envelope and pushed home until the insulating tube 30 seats against the step 29, thus ensuring accurate alignment and axial location of the electron gun, the helix and the collector electrode.

In the embodiment of Fig. 2, in which, as in Fig. 1, the various parts are not shown strictly to scale, the invention is applied to a travelling wave tube 31, differing considerably in appearance from the tube 1 of Fig. 1. In the tube of Fig. 1 the internal bores of the envelope portions 2 and 5 must be accurately coaxial to ensure proper support for the electron gun 3 and that the tube 30 mates correctly with the collector electrode 4. The electron beam has also to travel a considerable distance from the final anode 22 to the commencement of the helix, so making the apparatus considerably longer than the effective working part between the waveguides 10 and 11. (The apparatus external to the travelling wave tube, besides the input and output waveguide shown, comprises an assembly of magnetic focussing coils and means for supporting the travelling wave tube.) In the tube of Fig. 2, the external envelope 32 is a simple tube of glass, of relatively uncritical dimensions, forming a hermetic enclosure between a pair of end caps 33 and 34 between which the electrode structure of the tube is supported independently of the envelope 32. The general type of construction of this tube forms the subject matter of co-pending application of D. C. Rogers—P. F. C. Burke Serial No. 448,816, filed August 8, 1954. The tube has various other advantages and novel features of construction, but in the present specification only such parts of the tube and its associated apparatus will be described as is necessary for an understanding of the application of the present invention thereto.

An electron gun structure 35 is secured to the end cap 33 by means of a cylindrical skirt 36. The gun structure 35 comprises a hollow cylindrical outer member of magnetic material, which is the only part visible in the drawing of Fig. 2, closed at the end remote from the skirt 36, and the said outer member comprises, in itself, part of the final anode structure for the electron gun system, the actual anode being a copper insert in the front face 37. This cylindrical outer member also provides a magnetic shield for the electron gun system, one of the pole pieces for producing a magnetic field along the axis of the electron beam, and an inner waveguide choke sleeve member analogous to the member 8 of Fig. 1. At the other end of the travelling wave tube the end cap 34 has secured to it an electron collector electrode 38, which is shown provided with cooling fins 39, and a metal tube 40, through which the envelope 32 is evacuated, and which we shall refer to as pumping tube. The pumping tube provides the support at this end of the travelling wave tube for a unitary electrode assembly which comprises the remaining electrodes secured to the electron gun structure 35. This unitary assembly terminates, at the electron collector end of the tube, in a sleeve member 41 of ferromagnetic material, which forms, not only an inner quarter-wave-sleeve for a waveguide choke associated with the output waveguide of the apparatus, but also the other pole piece for the aforementioned axial magnetic focussing field. From the aspect of the present invention the electron gun structure 35 and the member 41 are directly analogous to the sleeve members 8 and 9 of Fig. 1 and carry between them a central tube of insulating material 42 having a precision bore supported on tubular bosses 43 and 44 projecting respectively from the front face 37 of the electron gun structure 35 and from the front face of the sleeve member 41. The helix 45, instead of terminating at either end in straight lengths of wire forming probe antennae as at 20, Fig. 1, are here brought straight out of the support tube 42 through slots 46 and are connected to respective generally U-shaped probe members 47, respectively secured to, and projecting from, the face 37 of the electron gun structure 35 and the opposing face of sleeve member 41. The type of probe member here shown is described and claimed in an application of D. C. Rogers Serial No. 407,732, filed February 2, 1954. The electron-gun structure 35 and the sleeve member 41 are secured together by means of three ceramic rods, of which two are indicated at 48. These rods 48 are fitted at their ends with sleeves having circular flanges 49, which are welded to the respective opposing surfaces of the electron gun structure 35 and sleeve member 41.

In operation the travelling wave tube 31 is inserted through input waveguide 50 and output waveguide 51, and is positioned axially so that the opposing faces of the electron gun structure 35 and the sleeve member 41 are aligned with the respective edges of the internal walls of waveguides 50 and 51. In place of the flange 15 of Fig. 1 an outer cylinder of ferromagnetic material 52 surrounds the electron gun structure and butts against the outer wall of the input waveguide. This cylinder forms part of the external magnetic circuit providing the focusing field referred to above and also forms the outer waveguide choke member, co-operating with the gun structure 35, to prevent leakage of electromagnetic wave energy from the waveguide 45 in the direction of the end cap 33; as it then effectively forms part of the outer wall of the waveguide it is copper-plated. The member 35 is not, in this case, a quarter wave length long, but rather is considerably more. The cylinder 52 has therefore preferably a section of small internal diameter a quarter wave length long abutting the waveguide and a longer section 53 of substantially larger bore. Thus the quarter wave choke is terminated in a line of considerably higher characteristic impedance which corresponds sufficiently to an open circuit to ensure that little R. F. power flows towards the end cap 33. It may be observed that from the magnetic circuit point of view the electron gun structure 35 projects beyond the end of the cylinder 52 by the thickness of the waveguide wall. If desired, the waveguide wall could be cut away so as to allow the cylinder 52 to be mounted flush with the inner surface of the waveguide rather than butting against the outer wall. On the other hand, we have found that, if anything, there is some advantage in having the inner pole piece member formed by the gun structure 35 projecting slightly beyond the cylinder 52.

At the other end of the travelling wave tube a cylinder 54, somewhat shorter than 52, but likewise of copper-plated ferromagnetic material, butts against the outer wall of waveguide 51. This member forms the other outer pole piece of the magnetic circuit providing the axial magnetic focussing field for the electron beam, so that the two members 41 and 54 together form, at the same time, one of the poles of the magnetic circuit and also a waveguide choke preventing escape of energy from the waveguide 51 in the direction of the end cap 34. In this case, however, it is convenient to make the member 41 a quarter wavelength long at the mean operating frequency (taking into account the effect of the intervening dielectric provided by the glass envelope 32) so that the members do form a quarter-wave choke.

Because of the large diameter of the envelope **32**, as compared with the envelope portion **5** of Fig. 1, the apertures in the waveguide walls surrounding the helix **45** are too large to be ignored; consequently the arrangement of Fig. 2 includes additional waveguide chokes in the form of quarter-wave sleeve members **55** and **56**, cooperating with respective flanges **57** and **58**, extending from the waveguide walls and surrounding the travelling wave tube between the two waveguides. For reasons of space, adjustable matching sections such as **12** and **13** of Fig. 1 with their pistons **14** are not provided in the arrangement of Fig. 2, for the piston would then foul the larger envelope **32**. Instead, closed matching sections **59** and **60**, respectively, are provided in continuation of the waveguides **49** and **50**, and at each end of the travelling wave tube, pairs of short circuiting rods, one rod being visible at either end at **61** and **62**, are positioned within the tube envelope above the extensions **59** and **60**, respectively. The short circuiting rods **61** are let in to the surface **37** of electron gun structure **35** and are secured in the sleeve member **55**, at the same time providing electrical connections thereto and mechanical support for the sleeve. Similar arrangements obtain at the other end of the tube, the pair of shorting rods **62** joining and supporting the sleeve member **56**. The sleeve members **55** and **56** are generally similar in construction to the sleeve members **8** and **9** of Fig. 1 but are apertured to permit passage of the ceramic rods **47** therethrough.

While the principles of the invention have been described above in connection with specific embodiments, and particular modifications thereof, it is to be clearly understood that this description is made only by way of example and not as a limitation on the scope of the invention.

What we claim is:

1. A travelling wave tube of the kind in which, during operation, a beam of electrons is projected along a waveguide structure in the form of a helical coil coupled by means including waveguide chokes to a hollow waveguide and interchanges energy with electromagnetic waves propagated along the said helical coil with a phase velocity approximately that of the said electrons, the said travelling wave tube comprising an electron gun structure, and an electron collector electrode, an assembly comprising a cylindrical tube of insulating material supporting said helical coil tubular sleeve members supporting said tubular member, means connecting said helical coil to said

tubular members, said members being positioned to form part of said waveguide chokes, means for rigidly connecting said electron gun structure to one of said tubular members, means for rigidly conecting said electron collector to the other of said tubular members, and a sealed outer envelope external of the tube assembly.

2. A travelling wave tube comprising: an electron gun for producing an electron beam; a helical coil of conducting material supported inside a tube of insulating material; a pair of waveguide choke inner sleeve members, each supporting one end of the said tube of insulating material; an outer envelope surrounding the said electron gun, the said tube of insulating material and the said sleeve members; an electron collector electrode closing the end of the said envelope opposite the electron gun; a tube of conducting material surrounding the electron beam secured to the structure of the electron gun and to the adjacent said sleeve member; and tubular supporting means surrounding the electron beam and secured to the other said sleevemember seated within the said electron collector electrode in such manner that the said sleeve member and the said electron collector electrode are insulated one from the other.

3. A travelling wave tube according to claim 2 in which the said tubular supporting means comprises a tube of insulating material engaging with the said electron collector electrode and having a conductive lining.

4. A travelling wave tube according to claim 1 in which the said sleeve members are each formed as a metal disc having a cylindrical skirt and an annular central boss which is inserted in the end of the helix supporting tube.

5. A travelling wave tube according to claim 1 wherein said means for connecting said helical coils each comprise a waveguide probe antenna secured to the corresponding sleeve member and joined to the adjacent end of the said helical coil, said cylindrical tube being slotted at this end for passage of the connection between the helix and the said probe antenna.

References Cited in the file of this patent

UNITED STATES PATENTS

2,602,148	Pierce	July 1, 1952
2,611,102	Bohlke	Sept. 16, 1952
2,672,571	Harman	Mar. 16, 1954
2,749,472	Field	June 5, 1956
2,774,006	Field et al.	Dec. 11, 1956