Sept. 10, 1968 C. H. DIX 3,401,298

NOISE REDUCTION IN A TRAVELLING WAVE TUBE EMPLOYING A HELIX INPUT COUPLER

Filed July 28, 1965

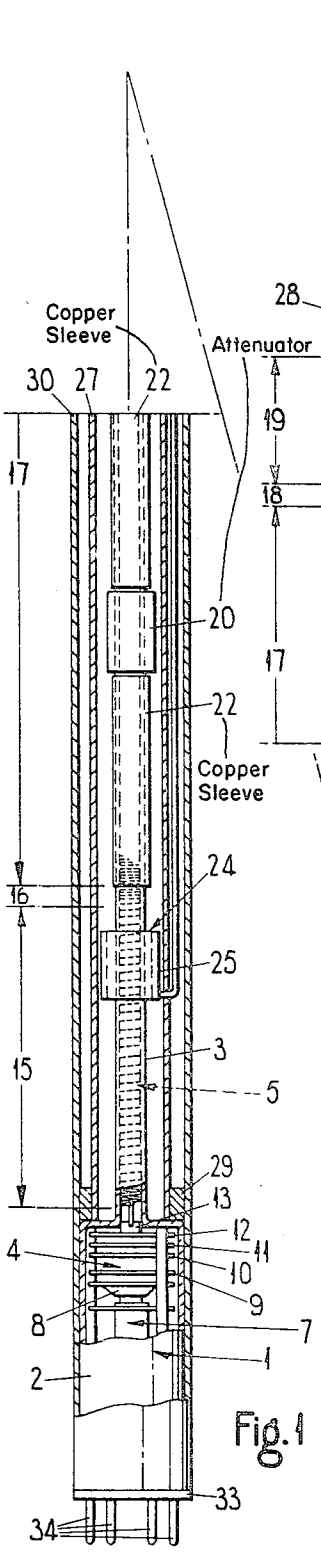


Fig. 1

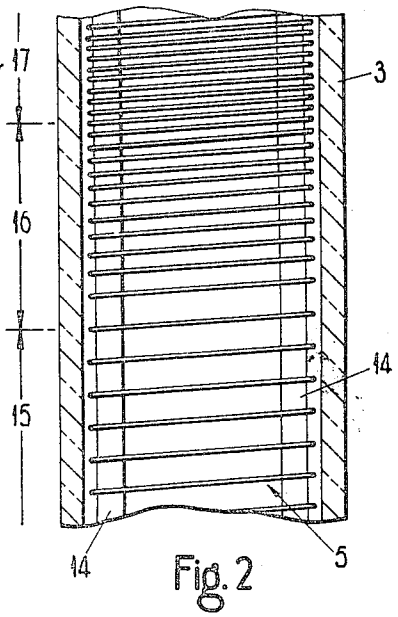


Fig. 2

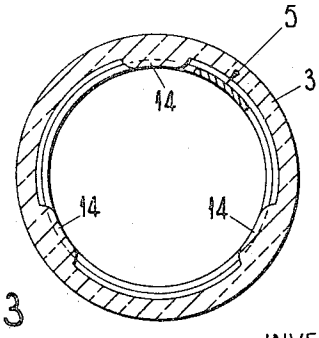


Fig. 3

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United States Patent Office 3,401,298
Patented Sept. 10, 1968

3,401,298

NOISE REDUCTION IN A TRAVELLING WAVE TUBE EMPLOYING A HELIX INPUT COUPLER

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Filed July 28, 1965, Ser. No. 475,366
Claims priority, application Great Britain, July 30, 1964, 30,220/64
9 Claims. (Cl. 315—3.6)

ABSTRACT OF THE DISCLOSURE

A helix type travelling wave tube wherein an input signal is launched onto a slow wave structure helix by means of an input coupler comprising a wire helix coaxially surrounding a further wire helix connected in series with the slow wave structure helix between an electron gun and the nearer end of the slow wave structure helix, the dimensions of the further helix differing from those of the slow wave structure helix so that noise on the electron beam at frequencies within the range of frequencies over which the tube is required to operate is not amplified over the length of the further helix.

This invention relates to travelling wave tubes.

The invention relates particularly to travelling wave tubes of the kind comprising an evacuated envelope in which is housed an elongated slow wave structure comprising a wire helix along which an electromagnetic wave may be propagated in a forward wave mode, and an electron gun for projecting an electron beam along the length of said structure so as to interact with a wave propagated along said structure.

It has been proposed to apply an input signal to such a tube by means of an input coupler comprising a wire helix coaxially surrounding a portion of the slow wave structure adjacent the electron gun. With regard to noise performance, however, such an arrangement has the disadvantage that while the input signal is not amplified until the end of the input coupler remote from the electron gun, noise signals are amplified from the end of the slow wave structure nearer the electron gun.

It is an object of the present invention to provide a travelling wave tube of the kind specified wherein this disadvantage is overcome.

According to the invention, in a travelling wave tube of the kind specified there is provided, between the electron gun and the end of the slow wave structure nearer the electron gun, a further wire helix disposed coaxial with and connected in series with the helix of the slow wave structure, and an input coupler comprising a wire helix disposed coaxially surrounding said further wire helix, the arrangement being such that over a band of frequencies an input signal may be launched from the input coupler onto the slow wave structure via said further helix, and such that at any frequency in said band the respective phase velocities of propagation of electromagnetic waves along said further helix and the slow wave structure differ sufficiently to ensure that when the electron beam has a velocity such that it can interact with an electromagnetic wave propagated along the slow wave structure, there can be no substantial interaction between the electron beam and an electromagnetic wave of the same frequency propagated along said further helix.

Preferably, said further wire helix has the same diameter as, but a different pitch from, the helix of the slow wave structure so that the two helices effectively form sections of a single helical structure of uniform diameter. The helical structure preferably also includes a transition

section in which the pitch varies monotonically with length between values corresponding to the pitches of said two helices; in order to obtain a good match over a broad band of frequencies the variation of the pitch in the transition section is preferably non-linear with the highest rate of variation at the end of the transition section adjacent the helix of the slow wave structure. With such an arrangement the helical structure may be supported directly within a tubular portion of the envelope of electrically insulating material, the helix of the input coupler closely surrounding said tubular portion.

One travelling wave tube in accordance with the invention and suitable for operation over the frequency band 200 mc./s. to 1,000 mc./s. whilst exhibiting good noise and limiting performance over this frequency range will now be described by way of example with reference to the accompanying drawings in which:

FIGURE 1 is a part sectional view of the travelling wave tube; and

FIGURE 2 is an enlarged diagrammatic view of part of the tube; and

FIGURE 3 is an end view of FIGURE 2.

Referring now to FIGURE 1, the tube includes an evacuated tubular glass envelope **1** comprising two communicating coaxial sections **2** and **3** of lengths 2.5 inches and 11.5 inches respectively. The section **2** houses an electron gun **4** arranged to project an annular electron beam coaxially through a slow wave structure, comprising part of a helical wire structure **5** housed in the section **3**, towards a collector electrode **6** sealed into the end of the section **3** remote from the section **2**.

The electron gun **4** is of conventional form and includes an indirectly heated ring-shaped cathode **7** provided with an active coating by a suitable coating technique, a frusto-conical beam forming electrode **8** and four coaxially aligned spaced apart apertured disc-shaped accelerating electrodes **9**, **10**, **11** and **12**. A thin-walled tubular metal member **13** of length 0.220 inch and internal diameter 0.203 inch extends coaxially from the side of the final accelerating electrode **12** remote from the cathode **7**. Leads (not visible) from the electron gun **4** are sealed through a plug of insulating material (not visible) sealed into the free end of the section **2**. The electron beam produced by the gun has a mean diameter of 0.110 inch and a thickness of .027 inch, and is focussed by means of an electromagnetic focussing coil (not shown) disposed around the outside of the tube in operation, which produces a uniform magnetic field of 450 gauss directed parallel to the axis of the envelope **1**.

Referring now also to FIGURES 2 and 3, the section **3** has a wall thickness of 0.025 inch and a nominal internal diameter of 0.230 inch, and at equally spaced positions around its internal surface there are formed three axially extending ribs **14**, the inner surfaces of the ribs **14** lying on a circumference of diameter 0.208 inch, and each rib **14** having a width of 0.06 inch.

The helical structure **5** is formed from 0.005 inch diameter molybdenum wire and has an internal diameter of 0.208 inch, each turn of the structure **5** being partially embedded in the ribs **14** so that the structure **5** is rigidly supported within the section **3**, the structure **5** being otherwise spaced from the internal surface of the section **3**.

The helical structure **5** has an overall length of 11 inches and comprises in series, starting from the end nearest the electron gun **4**; an input coupling section **15** of length 2.813 inches and having a pitch of 33 turns per inch; a first transition section **16** of length 0.188 inch in which the pitch changes exponentially from 33 to 100 turns per inch with the highest rate of change remote from the input coupling section **15**; an interaction

section **17** of length 6.625 inches and having a pitch of 100 turns per inch; a second transition section **18** similar to the transition section **16**, but in which the pitch decreases instead of increases; and an output coupling section **19** similar to the input coupling section **15**, but having a length of 1.188 inches.

The end of the helical structure **5** nearest the electron gun **4** is electrically connected to the free end of the metal tube **13** the end of the interaction section **17** being at a distance of 3 inches from the accelerating electrode **12**.

The tube further includes two tubular-shaped attenuators **20** and **21** (shown in outline only) which fit tightly around the outside of the part of the section **3** in which the interaction section **17** is housed, each attenuator **20** or **21** comprising a wire helix formed of 0.004 inch diameter tinned copper wire wound in the opposite sense to the helical structure **5**, a layer of carbon filled paper wrapped tightly around the outside of the wire helix, and a length of thermosetting polyester adhesive tape wound tightly around the inside of the wire helix and the outside of the carbon-filled paper layer. In the attenuator **20** the helix has a length of 0.75 inch and a pitch of 50 turns per inch, this attenuator **20** being disposed with its end nearer the electron gun **4** at a distance of 2 inches from the corresponding end of the interaction section **17**; in the other attenuator **21** the helix has a length of 0.5 inch and a pitch of 50 turns per inch, this attenuator **21** being disposed with its end nearer the electron gun **4** at a distance of 5 inches from the corresponding end of the interaction section **17**.

This section **3** also carries three closely fitting tubular copper sleeves **22** having a wall thickness of 0.004 inch, one sleeve **22** extending from the end of the attenuator **20** nearer the electron gun **4** for a distance of 2 inches towards the electron gun **4**, a second sleeve **22** extending between the two attenuators **20** and **21** and the third sleeve **22** extending from the end of the attenuator **21** nearer the collector electrode **6** for a distance of 0.875 inch towards the collector electrode **6**.

The tube also includes a third attenuator **23** of similar construction to those described above, the attenuator **23** being disposed around the end of the helical structure **5** adjacent the collector electrode **6**, and incorporating a double-wound helix (not visible) of length of 0.3 inch and pitch 16 turns per inch formed from 0.004 inch diameter tinned copper wire.

An input signal is supplied to the tube via a coupler **24** comprising a wire helix (not visible) of length 0.625 inch and pitch 18 turns per inch formed from 0.036 inch diameter copper wire and wound in the opposite sense to the helical structure **5**. The coupling helix is housed within and spaced from a short metal tube **25** and is disposed around the part of the envelope **1** housing the input coupling section **15** of the helical structure **5**. An output signal is derived from the tube via a similarly constructed output coupler **26** disposed around the part of the envelope **1** in which the output coupling section **19** of the helical structure **5** is housed.

The section **3** together with the associated attenuators **20**, **21** and **23**, copper sleeves **22** and input and output couplers **24** and **26** is housed coaxially within a tubular metal enclosure **27** one end of which abuts against the shoulder between the sections **2** and **3** and the other end of which lies about 2 inches beyond the collector electrode **6**. At a position adjacent the collector electrode **6** the metal enclosure **27** carries a bush of magnetic material **28** which serves as a pole piece for the magnetic field required to focus the electron beam. A second annular pole piece **29** for this field is coaxially disposed around the envelope **1** adjacent the electron gun **4**.

The metal enclosure **27** and the section **2** are coaxially surrounded by a tubular metal casing **30** which extends between a metal boss **31** at the end of the metal enclosure **27** nearest the collector electrode **6**, to which boss

31 a lead **32** from the collector electrode **6** is electrically connected, and a conventional valve base **33** disposed adjacent the electron gun **4** and to the pins **34** of which the leads (not visible) from the electron gun **4** are connected.

Coaxial leads **35** from the input and output couplers **24** and **26** extend along the tube via the space between the metal enclosure **27** and the metal casing **30**, through apertures (not visible) formed in the pole piece **28** and through further apertures (not visible) in the metal boss **31**. The inner of each coaxial lead **35** is connected at the relevant end to that end of the appropriate coupling helix **24** or **26** remote from the interaction section **17** and the corresponding end of the outer is connected to the metal tubular member **25**, in which that coupling helix is housed. At their other ends the coaxial leads **35** are provided with conventional coaxial sockets **36**.

In operation of the tube, with the electron beam having a mean velocity corresponding to a voltage of 35 volts and a current density of 5 milliamps per square centimetre, a gain of between 20 dbs. and 40 dbs. is obtained over a bandwidth of from 250 megacycles per second to 1,000 megacycles per second. A noise figure of less than 10 dbs. is obtained over this frequency range with the beam voltage adjusted for minimum noise, and the saturated power output of the tube is in the range −13 dbm to −3 dbm, this output being maintained over a 40 dbs. range of input power variation.

It will be understood that the low noise figure is in part attributable to the fact that, due to the difference in the phase velocity of propagation of electromagnetic waves between the interaction and input coupling sections **17** and **15**, noise is not amplified until the beginning of the interaction section **17**, that is, the same point at which amplification of the input signal begins. The length of the input coupling section **15** thus effectively constitutes part of a field free drift length, which is also partly constituted by the length of the metal tube **13**, this drift length being chosen, in accordance with known considerations, to improve the performance of the tube in respect of noise.

The transition sections **16** and **18** are included to give a good match between the coupling and interaction sections **15**, **19** and **17**, an exponential change in pitch having been found most suitable for this purpose.

The two attenuators **20** and **21** surrounding the helical structure **5** serve to prevent oscillation in known manner, two attenuators rather than one being used to assist in reducing reflections which tend to occur at the output end of the attenuator and at the ouput coupler if only one attenuator is used.

The attenuator **23** adjacent the collector electrode serves to absorb any electromagnetic wave energy not extracted via the output coupler **26**; this is found necessary since the output coupler **26**, being open circuit at its end nearer the collector electrode **6**, tends to give rise to reflections. The input coupler **24** is not found to suffer from this difficulty because it is terminated by the tube **13**.

The copper sleeving **22** surrounding the major portion of the interaction section **17** serves to decrease the dispersive properties of the interaction section **17** at the low frequency end of the operating band of the tube, thus improving the flatness of the frequency/gain characteristic of the tube. The presence of the sleeving **22** is also found to increase the gain of the tube at the high frequency end of the operating band when the tube is operated so as to obtain a minimum noise figure. This is thought to be due to the fact that under least noise conditions the beam velocity is nominally slightly less than the phase velocity of the wave propagated along the interaction section **17** and the effect of the sleeving **22** is to lower the latter velocity at higher frequencies. In addition the sleeving **22** is found to improve the limiting performance of the tube.

I claim:

1. A travelling wave tube comprising: an evacuated envelope in which is housed an elongated slow wave structure including a wire helix along which an electromagnetic wave may be propagated in a forward wave mode; an electron gun for projecting an electron beam along the length of said structure so as to interact with a wave propagated along said structure; a further wire helix disposed coaxial with and connected in series with the helix of the slow wave structure between the electron gun and the end of the slow wave structure nearer the electron gun; and an input coupler comprising a wire helix disposed coaxially surrounding said further wire helix so that over a band of frequencies an input signal may be launched from the input coupler onto the slow wave structure via said further helix; the dimension of the further helix and the helix comprising the slow wave structure being different so that at any frequency within said band the phase velocities of propagation along the further helix and the slow wave structure differ sufficiently to ensure that when the electron beam has a velocity such that it can interact with an electromagnetic wave propagated along the slow wave structure, there can be no substantial interaction between the electron beam and an electromagnetic wave of the same frequency propagated along said further helix.

2. A travelling wave tube according to claim 1 in which there is provided beyond the end of the slow wave structure remote from the electron gun an additional wire helix disposed coaxial with and connected in series with the helix of the slow wave structure, and an output coupler comprising a wire helix disposed coaxially surrounding said additional wire helix.

3. A travelling wave tube according to claim in which said further wire helix has the same diameter as but a different pitch from the slow wave structure so that the slow wave structure and said further wire helix effectively constitute different sections of a single helical wire structure of uniform diameter.

4. A travelling wave tube according to claim 3 in which said helical wire structure also includes a transition section between the slow wave structure and said further wire helix, the transition section having a pitch which varies monotonically with length from a value at the end adjacent the slow wave structure substantially equal to the pitch of the slow wave structure to a value at the end adjacent said further helix substantially equal to the pitch of said further wire helix.

5. A travelling wave tube according to claim 4 in which the pitch of the transition section varies non-linearly with the highest rate of variation at the end of the transition section adjacent the slow wave structure.

6. A travelling wave tube according to claim 5 wherein the pitch of the transition section varies exponentially.

7. A travelling wave tube according to claim 3 in which said helical wire structure is supported directly within a tubular portion of the envelope which consists of an electrically insulating material, the input coupler surrounds the part of said tubular portion which houses said further wire helix, and there are provided at least two attenuators fitting around different sections of the part of said tubular portion which houses the slow wave structure.

8. A travelling wave tube according to claim 4 wherein there is provided beyond the end of the slow wave structure remote from the electron gun an additional wire helix disposed coaxial with and connected in series with the helix of the slow wave structure, and an output coupler comprising a wire helix disposed coaxially surrounding said additional wire helix being of substantially the same dimensions as said further wire helix and being connected to the slow wave structure via a transition section of substantially the same dimensions as the transition section between the slow wave structure and said further wire helix.

9. A travelling wave tube according to claim 8 wherein the slow wave structure, the further and additional wire helices and the transition sections form sections of a single helical wire structure of uniform diameter which is supported directly within a tubular portion of the envelope of electrically insulating material with the input and output couplers surrounding the parts of said tubular portion housing said further and additional wire helices respectively, and there is provided an attenuator fitting around a part of said tubular portion housing a part of the helical structure lying on the side of the output coupler remote from the electron gun.

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