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TRAVELING WAVE TUBE

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FIG. 1

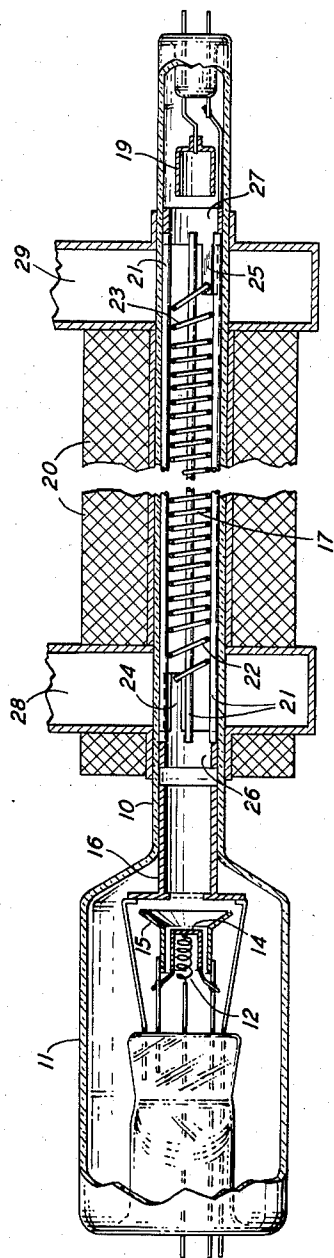


FIG. 3

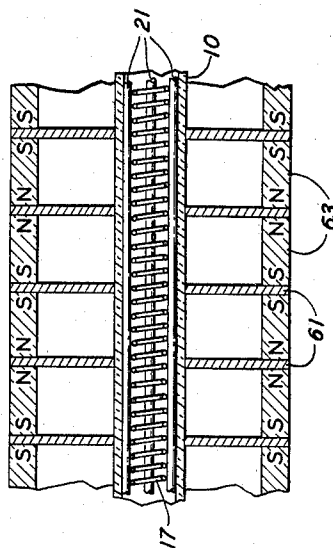


FIG. 2

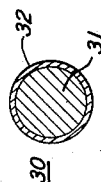
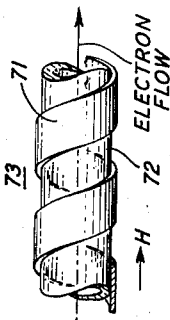


FIG. 4



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TRAVELING WAVE TUBE

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5 Claims. (Cl. 315—3.5)

The present invention relates to the focusing of electron beams over a relatively long path. The invention has special application to traveling wave tubes which utilize the interaction between a traveling electromagnetic wave and an electron beam over a plurality of operating wavelengths to secure gain to the wave.

Among the most useful form of traveling wave tubes is one which incorporates a helically wound conductor as the wave circuit for propagating the slow electromagnetic wave for interaction with the beam which is projected axially therethrough. In one aspect the present invention relates particularly to such a helix-type traveling wave tube.

In such a tube, it is generally important to employ some focusing action for keeping the beam in alignment with the helix. Such focusing is needed because the space charge forces in the beam tend to make it diverge. Divergent electrons tend to impinge on the circuit resulting in noisy operation, loss of efficiency, and maybe even damage thereto. One of the most common expedients for achieving this focusing action has been the use of a longitudinal magnetic field, either unidirectional or time-constant spatially-alternating, along the path of flow. However, the requirements on this magnetic field are rather severe, posing difficult problems of minimizing transverse components and maintaining accurate alignment of the tube and the flux supplying equipment.

One object of the present invention is to ease the stringent requirements on the magnetic field used in focusing the electron beam in helix-type traveling wave tubes.

In accordance with this end, it is found that an appreciable easing of the requirements on the accuracy of alignment and on the need for magnetic shielding is achieved by making the helix of a magnetic material so long as the coercive forces of the material are low and the helix does not saturate magnetically.

In some very early forms of traveling wave tubes, the helix was made of iron. The choice of iron for the helix in such tubes was motivated by the desire for a material of a relatively high radio frequency loss to provide a distributed loss along the wave circuit. Such a distributed loss was useful for tube stability. However, it was not then appreciated that the use of a magnetic material for the helix would be useful in relieving the stringencies of the magnetic focusing field. On the other hand, it was there found that the use of a magnetic material such as iron for the helix resulted in a degradation of the focusing. This degradation of focusing because of the use of iron can now be explained by the fact that unless it is properly alloyed and annealed iron has a high coercive force, such as .75 oersteds or higher, which results in the formation of free poles on an iron helix. Such poles set up random magnetic field components, transverse to the helix axis, which disturb the electron flow. Moreover, as a result of these early disappointments with iron helices, it became the general practice to avoid the use of magnetic materials in the wave interaction circuit structures.

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It is in accordance with one aspect of the present invention to utilize as the wave interaction circuit of a helix type traveling wave tube a helix of suitable magnetic material. In contradistinction to the magnetic helices of the kind utilized unsuccessfully hitherto as described above, the magnetic helices of the invention have sufficiently low coercive forces to avoid the setting up of free poles when positioned in the applied magnetic focusing fields. Moreover, it is also important that the dimensions of these helices be such that magnetic saturation is avoided. In further contradistinction to magnetic helices of the prior art, one aspect of the present invention contemplates the use of a magnetic helix which presents relatively low loss to radio frequency waves propagating therealong except along selected portions where high loss is desired for tube stability. Features of the invention can be combined, for example, in a composite helix which has a core of magnetic material of low coercive force but relatively high radio frequency loss, such as Kovar, and which has selected portions thereof coated with a layer of a highly conductive material, such as silver.

In a broader aspect, the invention relates to the focusing of a cylindrical electron beam by coaxially surrounding the path of flow with a magnetic helix of low coercive force and high saturation magnetization and providing a magnetic field in a direction parallel to the helix axis. Such helix serves as a flux guide for reducing the effect of external transverse magnetic field components and correcting for any misalignment in the direction of the applied magnetic field.

The invention will be better understood from the following more detailed description taken in conjunction with the accompanying drawings in which:

Fig. 1 shows a helix-type traveling wave tube which utilizes a unidirectional magnetic focusing field and in which the interaction circuit is of a magnetic material of low coercive force in accordance with one aspect of the invention;

Fig. 2 is a cross-section of the conductor forming the helix wave circuit used in the tube shown in Fig. 1;

Fig. 3 shows a portion of a helix-type traveling wave tube, essentially of the kind shown in Fig. 1, which utilizes a time-constant spatially-alternating magnetic field for focusing the electron beam; and

Fig. 4 shows a portion of an electron beam tube which employs a magnetic helix as a flux guide external to the tube envelope in accordance with another aspect of the invention.

Referring now particularly to Fig. 1, there is shown an illustrative embodiment of a helix-type traveling wave tube adapted to be used as an amplifier for microwave frequencies. This traveling wave tube is essentially of the kind described in United States Patent 2,575,383 which issued to L. M. Field on November 20, 1951, differing therefrom primarily in the nature of the helix interaction circuit and the arrangement for making this circuit lossy for suppressing the tendency to self-oscillation. The various tube elements are enclosed in an evacuated glass envelope having an elongated portion 10. This portion, which is of uniform diameter along its length, connects with an enlarged portion 11 which houses an electron gun for producing an electron beam. The electron gun shown comprises a heater 12 which is supplied with energy from a suitable voltage source not shown, a cathode 14, and an apertured electrode 15 for forming the electrons emitted from the cathode into a concentrated stream. One side of heater 12 is connected to cathode 14. A metallic cylindrical electrode 16 having a surface configuration which will provide suitable electron field patterns is biased to a positive potential with respect to the cathode 14 in order to accelerate and focus the electron stream. The

electron stream is further concentrated and guided along an axial path within the space surrounded by the helix 17 and by the solenoid 20 which provides an axial magnetic field. In accordance with a feature of the invention the helix 17 is of a magnetic material having a low coercive force. Typical materials include alloys known by the trade names of Kovar and Permalloy which generally have coercive forces of .2 oersteds or less. The alloy Kovar is usually made of 29 percent nickel, 17 percent cobalt, 0.3 percent magnesium, the remainder being iron. A desirable constituency for the alloy Permalloy may be 78.5 percent nickel, 3.8 percent molybdenum, and the remainder iron. The strong magnetic field formed by the solenoid 20 serves to prevent the deviation of the electron stream from the desired path by providing strong confining forces. Target electrode 19 serves to collect the electrons arriving at the end of the elongated portion 10 of the envelope. In the operation of the device, the accelerating electrode 16 and the helix 17 are maintained at suitably positive potentials with respect to the cathode 14 by a suitable voltage source not shown. The target electrode 19 is maintained at a somewhat lower positive potential.

The helix 17 is supported by a series of non-conductive ceramic rods 21 which are disposed between the helix and the envelope. These supporting rods act to hold the helix firmly in a position concentric with the tubular envelope.

There is provided at the input end of the helix 17, i. e., the end adjacent the electron source, a hollow cylindrical metallic section 26 which supports an input coupling strip 24. At the output or target end of the helix 17, a similar cylindrical section 27 supports an output coupling strip 25.

The helix 17 is joined to the input coupling strip 24 by the input impedance matching section 22 and to the output coupling strip 25 by the output impedance matching section 23. These matching sections are simply extensions of the helix in which the spacing between turns is increased and serve to provide a wave transmission path of uniformly changing impedance from the relatively high impedances at the end of each of the coupling strips to the relatively low impedance of the central portion of the helix.

Input wave energy is applied to the input coupling strip 24 by way of the input wave guide 28. At the output end, the output wave guide 29 serves to guide the amplified output wave from the output coupling strip 25 to utilization apparatus. In operation, the input wave guide 28 is coupled to a source of signal energy so as to produce a mode of wave propagation having an electric field vector parallel to the coupling strip 24.

A corresponding wave is thus generated along the coupling strip and imparted to the helix through the impedance matching section 22. The wave then travels along the circumference of the helix at a speed approximately that of light, but at a linear velocity along the axis of the tube which is much slower. The velocity of the electron beam past the helix is adjusted to be synchronous with the axial wave velocity by the choice of the potential applied to the helix.

As has been indicated above, it is important that the electron beam have no transverse or radial components as it flows past the helix. To this end, the solenoid 20 provides a longitudinal magnetic field which tends to minimize such radial components. However, it can be appreciated that if the longitudinal magnetic field is not aligned exactly with the axis of the helix there will exist within the helix transverse magnetic field components unless some provision is made for their elimination. It is in accordance with one aspect of the invention to utilize the helix 17 not only as the wave interaction circuit, but also as a flux guide for eliminating such internal transverse components. To this end the helix is made of a material which is magnetic with a low coercive force and is proportioned not to saturate in the applied magnetic

field. It is found that such a helix wound to have a pitch angle of about 3.6 degrees (corresponding to a 1000 volt electron beam) can reduce in its interior region the strength of transverse magnetic components existing outside the helix by more than 90 percent. On the other hand, it is found that the shunting effect of such a helix to magnetic field components parallel to its axis is no more than a few percent. However, if the helix becomes saturated by the longitudinal magnetic field, its effect on transverse magnetic fields is appreciably lessened.

In a traveling wave tube of this kind it has usually been found desirable to introduce loss along the helix so as to provide dissipations of any waves reflected from the output end backwards towards the input end. In tubes known hitherto, such loss has been achieved by spraying resistive material along the wave path, for example, on support rods. In the case where the helix is of a magnetic material which itself exhibits high loss to radio frequency wave energy, it should be unnecessary to introduce any additional loss. In general, moreover, it will be desirable to minimize along a considerable length of the helix the loss inherent in the use of such magnetic material. To this end, it is advantageous to coat a helix, of a high loss magnetic material such as Kovar or Permalloy, with a low loss material such as silver or gold. To achieve a desired loss distribution this coating is deposited selectively, varying from large thicknesses where a low loss is desired, to zero thicknesses where appreciable loss is desired. In Fig. 2 there is shown in enlarged view a cross-section of a conductor 30 suitable for use in this tube comprising a kovar core 31 coated with a layer of silver 32.

The principles of the invention are equally applicable to focusing arrangements which utilize a time-constant spatially-alternating longitudinal magnetic field. As is described in greater detail in J. R. Pierce Patent 2,847,607, issued August 12, 1958, where a number of suitable arrangements are disclosed, a focusing arrangement utilizing a periodic magnetic field permits a considerable saving in the weight and size of the flux producing equipment necessary.

Fig. 3 shows for purposes of illustration a portion of the elongated portion of the traveling wave tube 10 shown in Fig. 1 with which is associated a typical periodic magnetic field focusing arrangement. A series of annular cylinders 61 of a magnetic material are spaced apart along the path of flow surrounding the tube envelope to serve as pole pieces. A series of annular cylindrical permanent magnets 63, magnetized in an axial direction also are positioned along the path of flow, successive magnets bridging adjacent pairs of pole pieces and being reversed in sense in the manner shown, whereby adjacent pole pieces are oppositely poled. Such an arrangement provides along the path of electron flow a succession of regions of longitudinal magnetic field, the direction of the field reversing with successive regions. In such an arrangement too, by making the helix of a magnetic material of low coercive force and of sufficient bulk so as not to become saturated, transverse magnetic field components along the path of flow will be appreciably reduced with little effect on the longitudinal component. The term "low coercive force" as used in the present specification refers to values of coercive force significantly less than of annealed iron (.75 oersteds) and advantageously no more than those of Kovar and Permalloy (.2 oersteds).

In Fig. 4 there is illustrated in enlarged scale an arrangement in which a helical flux guide 71 of a suitable magnetic material surrounds the elongated portion of the non-magnetic envelope 72 of an electron beam device 73 through which is projected an electron beam and which is positioned in a substantially axial magnetic focusing field H. In this arrangement, the helix flux guide 71 serves only to minimize components of magnetic field transverse to its axis and, accordingly, only

considerations applicable to the focusing need be of concern. The electron beam device, if a traveling wave tube, can utilize any of various forms of suitable interaction circuits. Alternatively, the electron beam device can be of the kind which does not employ a wave interaction circuit along the path of flow. For example, various forms of space charge amplifiers are known which do not utilize wave circuits. Typical are double stream tubes of the kind described in United States Patent 2,652,513 which issued on September 15, 1953 to A. V. Hollenberg. It is to be understood that the various arrangements illustrated are merely illustrative of the general principles of the invention. Various other modifications will be evident to workers skilled in the art without departing from the spirit and scope of the invention. In particular, it may be possible to utilize for the helical flux guide a ferromagnetic material which in the presence of the longitudinal magnetic field will exhibit non-reciprocal attenuation properties because of gyromagnetic resonance phenomena. However, in such instances it is important that the material be of low coercive force so that free poles will not be set up and also that the dimensions be such that a state of magnetic saturation is avoided. Additionally, it may be possible to utilize a helix interaction circuit of magnetic material of low coercive force which, although normally exhibiting high loss to radio frequency waves, acts as a very low loss wave guiding circuit in the presence of a longitudinal magnetic field of such value as to produce ferromagnetic resonance.

What is claimed is:

1. In a traveling wave tube, an electron source and target electrode for defining therebetween a path of electron flow, means for establishing a longitudinal magnetic field along the region of and parallel to said path of electron flow, means for minimizing transverse magnetic field components in the vicinity of the path of flow, said means comprising a helical conductor of a material having a high magnetization saturation and having a coercive force less than .2 oersted positioned in said magnetic field and surrounding the electron beam.

2. In a traveling wave tube utilizing the interaction between an electromagnetic wave propagating along a helix and an electron beam, an electron source and target elec-

trode for defining therebetween a path of electron flow, means for establishing a magnetic field along the region of and parallel to said path of electron flow for minimizing transverse components of electron flow, and means for minimizing transverse magnetic field components in the vicinity of the path of flow, said means comprising a helical conductor of a material having a high magnetization saturation and having a coercive force less than .2 oersteds surrounding said electron beam and having its axis parallel with said electron beam.

3. A traveling wave tube in accordance with claim 2 wherein said helix is characterized by a highly conductive coating on select turns of said helix.

4. A traveling wave tube comprising means for forming an electron beam, means for establishing a uniform magnetic field parallel to and in the direction of flow of said beam for minimizing transverse components in said beam, means for propagating an electromagnetic wave in coupling proximity with said electron beam, said last mentioned means including a helical conductor of magnetic material and having a coercive force less than .2 oersted positioned in said magnetic field and surrounding said electron beam, said helical conductor further comprising a material of high conductivity selectively distributed therealong.

5. In a traveling wave tube, means for forming an electron stream, means for establishing a uniformly spatially alternating periodic magnetic field along the path of said stream for minimizing transverse components of electron flow, means for minimizing transverse components of the magnetic field in the vicinity of the path of flow, said last mentioned means comprising a helical conductor of a magnetic material having a coercive force less than .2 oersted positioned in said magnetic field and surrounding said electron stream.

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