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2,821,652

MULTIHELIX TRAVELING WAVE TUBES

Filed Oct. 6, 1952

2 Sheets-Sheet 1

FIG. 1

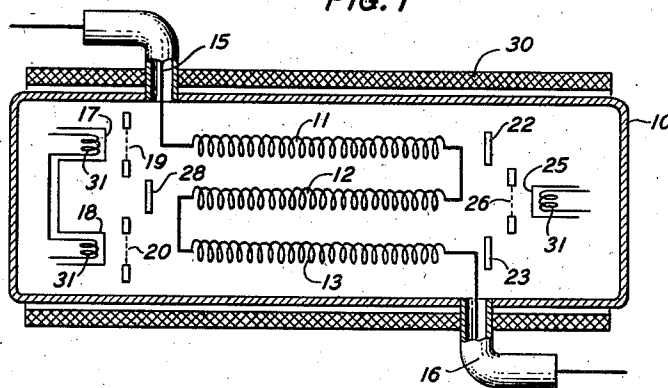


FIG. 4

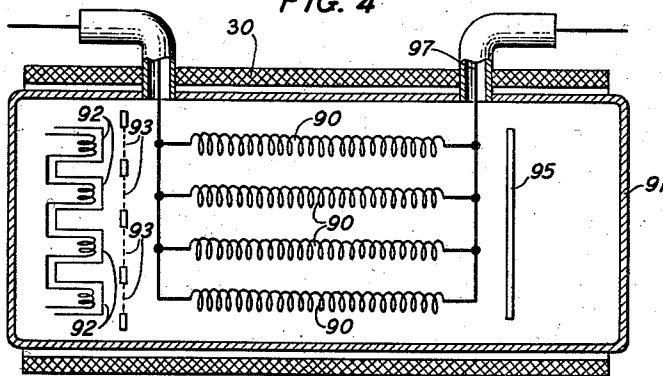
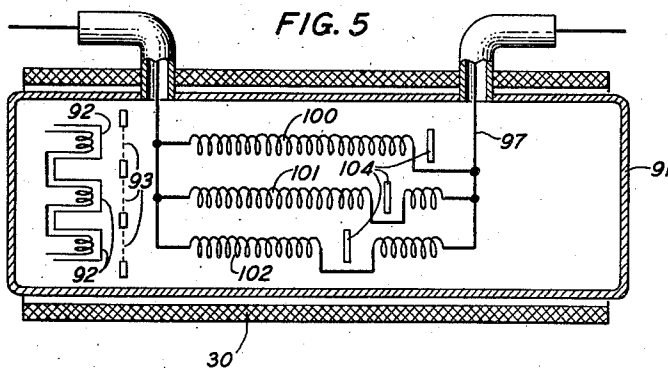


FIG. 5



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FIG. 2

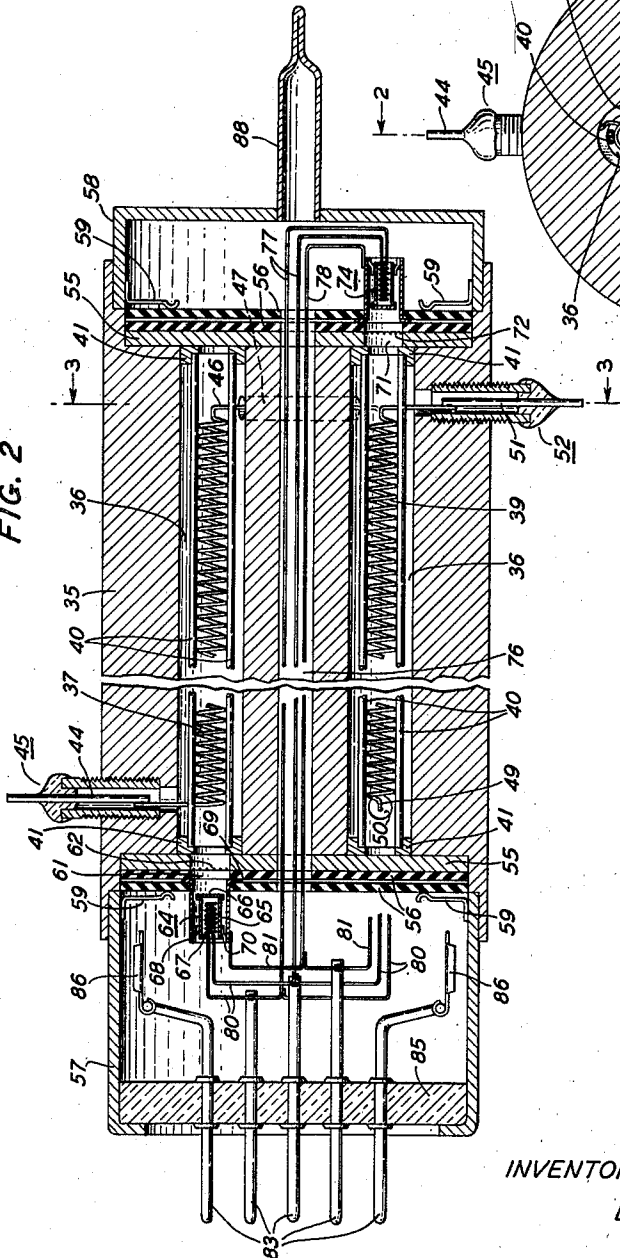
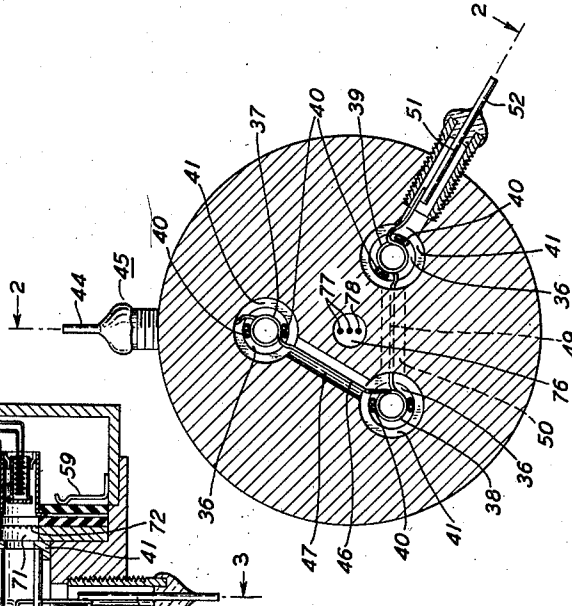


FIG. 3



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MULTIHELIX TRAVELING WAVE TUBES

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Application October 6, 1952, Serial No. 313,252

10 Claims. (Cl. 315—3.6)

This invention relates to electron discharge devices and more particularly to such devices known as traveling wave tubes, wherein the electromagnetic waves of an electron beam and an applied signal interact to amplify the signal.

In such tubes, gain or amplification of a signal over a band of frequencies depends upon the velocity of the electron stream being properly correlated to the axial velocity of the signal wave. The velocity of the applied electromagnetic wave is slowed down, by the transmission circuit employed, so that the velocity of the electron stream is slightly greater than that of the applied electromagnetic wave. Transmission circuits that have been employed to delay the applied electromagnetic wave include helices, resonators, filter circuits, etc. of which the most frequently employed has been the helical transmission circuit or helix. The velocity of the applied electromagnetic wave is determined by, inter alia, the pitch at which the helix is wound and the diameter of the helix; for a smaller diameter or a wider winding pitch the velocity of the electromagnetic wave is increased. The velocity of the electron stream is determined by, inter alia, the voltage existing between the cathode and the accelerating electrode of the gun.

While there is an optimum correlation between the velocities of the electromagnetic wave and the electron stream for maximum gain, if other factors are considered constant, that correlation can only be obtained for a single frequency of operation, as the frequency of the applied signal is also determinative of the speed of the electromagnetic wave in traversing the helix. It has therefore been the practice to design the helix and the electron gun for optimum gain at a single mid-band frequency and to accept less gain for signals varying from that mid-band frequency within an accepted range.

It is one object of this invention to increase the frequency range over which optimum gain will occur.

It is a further object of this invention to attain a high gain with a reduction in the overall tube length. In prior traveling wave tubes high gain has been attained by increasing the length of the interaction region, i. e., by increasing the length of the helix with a resultant elongated structure. In accordance with this object of this invention, high gain is attained with a traveling wave tube whose overall length is considerably shorter than that of prior equivalent tubes.

A still further object of this invention is to decrease the overall weight and size of a traveling wave tube. This is effected by reducing the required magnetic field structure. Thus it is an object of this invention to utilize more completely and more efficiently the magnetic field of the tube.

These and other objects of this invention are achieved in accordance with this invention by employing a plurality of helices within a single traveling wave tube. In accordance with this invention, these helices advantageously may be designed for different mid-band frequencies, such

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as mid-band frequencies 50 megacycles apart, so that optimum gain is attained over a wide frequency range.

In one specific embodiment of this invention, a plurality of helices are positioned in parallel within the envelope of the traveling wave tube. The end of one helix is connected to a coaxial input terminal and an end of another helix is connected to a coaxial output terminal, the remaining ends being coupled to each other. The helices may be so arranged that adjacent ends are coupled to each other, in which case the direction of electron flow will alternate in adjacent helices. In one specific embodiment employing three such helices, two electron guns and one collector electrode are positioned at one end of the tube while two cooperating collector electrodes and one electron gun are positioned at the opposite end of the tube.

In accordance with this invention, the helices are designed to have different mid-band frequencies. This may be attained by varying the diameter of the helix or by varying the pitch of the helix. In one specific embodiment, the frequencies are 450 megacycles, 500 megacycles, and 550 megacycles, the frequency pass band being thus centered at 500 megacycles.

In a further specific embodiment of this invention, the helices are positioned in parallel within the traveling wave tube and have their one ends connected in parallel to the coaxial input terminal and their other ends connected in parallel to the coaxial output terminal.

It is therefore a feature of this invention that a plurality of helices be employed within a single traveling tube.

It is a further feature of this invention that the mid-band frequency of these helices be different whereby optimum gain is attained over a wide frequency range.

It is a further feature of certain specific embodiments of this invention that the helices be positioned in parallel within the traveling wave tube whereby the overall length of the tube is reduced.

It is a further feature of certain of these embodiments that the helices be connected in series to attain increased gain while it is a further feature of certain other of these embodiments that the helices be connected in parallel to attain increased power output.

Further, it is a feature of one specific embodiment of this invention wherein the helices are connected in series that the collector electrodes comprise conducting plate members having apertures therein across which apertures a plurality of fine wires extend defining the accelerating electrodes of the electron guns at that end of the tube.

Further, it is a feature of another specific embodiment of this invention wherein the helices are connected in parallel that the collector electrodes be positioned different distances from the input to the parallel helices and that the remainder of the helix be behind the collector electrode to the common output terminal, whereby the turns of the helices behind the collector electrodes provide regions where no interaction with the electron beam occurs. These regions can thus serve to equalize the phases of the signals traveling along the parallel helices so that phase dispersion does not occur at the common output terminal.

A complete understanding of this invention and of the aforementioned and various other features thereof may be gained from the following detailed description and the accompanying drawing, in which:

Fig. 1 is a schematic representation of a traveling wave tube in accordance with one specific illustrative embodiment of this invention wherein a number of helices are connected in series within a single traveling wave tube;

Fig. 2 is a sectional view of a tube in accordance with the embodiment of Fig. 1;

Fig. 3 is a cross-sectional view of the tube of Fig. 2 taken along the line 3—3;

Fig. 4 is a schematic representation of another specific illustrative embodiment of this invention wherein the helices are connected in parallel; and

Fig. 5 is a schematic representation of another specific illustrative embodiment of this invention.

Referring now to Fig. 1, the specific embodiment there depicted comprises an envelope 10 in which are located a plurality of helices, such as three helices 11, 12 and 13. One end of helix 11 is connected to an input coaxial terminal 15 and one end of helix 13 is connected to an output coaxial terminal 16. The ends of helix 12 are connected to the other ends of helices 11 and 13 so that the three helices are connected in series. Cathodes 17 and 18 are positioned at one end of the envelope 10 for projecting streams of electrons through accelerating grids 19 and 20 and along helices 11 and 13; collector electrodes 22 and 23 are positioned at the opposite end of the envelope 10 adjacent the other end of helices 11 and 13. A cathode 25 together with an accelerating grid 26 are positioned with the collector electrodes 22 and 23 for projecting a stream of electrons along the helix 12 and a collector electrode 28 cooperating therewith is positioned adjacent the other end of helix 12 adjacent the accelerating grids 19 and 20. Advantageously the accelerating grids and collector electrodes may be mounted by a common support member at each end of the envelope 10, as described further below with reference to Fig. 2. The magnetic field may be provided by a solenoid 30 encompassing the envelope 10, and suitable heater elements 31 are provided for each of the cathodes 17, 18 and 25.

In the operation of this embodiment of the invention, the electromagnetic signal to be amplified is applied by the coaxial input terminal 15 to the gun end of the helix 11 and travels down the helix 11 during which travel interaction takes place between the wave and the electron stream projected therealong, as is known in the art. After traveling down the helix 11 the signal wave is then shunted over directly to the helix 12 and travels back along it, at the same time interacting with a second and distinct electron stream. Similarly after traveling along the helix 12 the signal wave is shunted over to the helix 13 and travels along it while interacting with a third separate and distinct electron stream. After traveling down the helix 13 the signal wave is advantageously removed from the tube by the coaxial output terminal 16. Thus the direction of both electron flow and the travel of the signal wave alternates in successive helices. By connecting the helices in series, a high overall gain can be attained without unduly increasing the length of the traveling wave tube. As the magnetic field must be present along the length of the tube this further means that a high gain can be attained with a shorter magnetic field, thereby attaining considerable savings in field structure and reducing the size, weight, and cost of the field structure. By thus utilizing a single magnetic field for three helices which are positioned in parallel but connected in series, a more efficient utilization of the field structure is attainable.

Advantageously in accordance with one aspect of this invention the three helices 11, 12 and 13 are not identical but are so wound as to have different mid-band frequencies at which optimum gain is attainable. Specifically the pitch or the internal diameter of each of the helices is different. Advantageously in one specific embodiment one helix is designed for optimum gain at 450 megacycles, a second helix for optimum gain at 500 megacycles, and a third helix for optimum gain at 550 megacycles. Thus the band width of the tube and particularly the frequency region at mid-band for optimum gain is increased as over a portion of its travel through the tube, the signal wave will pass through three different frequency regions of optimum gain. No dis-

cernible difference has been found as to the order in which the signal waves are applied to the helices. While a slight impedance mismatch is introduced by providing helices of either different internal diameters or pitches, that mismatch can be tolerated if the frequency difference between the helices is not too great. However, if desired, the pitch at the ends of the helices may further be varied to provide a better impedance match between successive helices.

Turning now to Figs. 2 and 3 there is shown one specific structural embodiment of this invention in accordance with the embodiment of Fig. 1. As there seen, the tube comprises a metallic housing member 35 having a plurality of parallel bores 36, such as three. A helix 37, 38 or 39 is positioned in each bore and is supported therein by pairs of support rods 41 positioned contiguous each other at opposite sides of the helix whereby the helix is securely supported while allowing a high degree of flexibility to aid in mounting the helix in place, as further described in application Serial No. 298,230, filed July 11, 1952, by G. H. Robertson. The support rods 40 are mounted by support rings 41 advantageously secured, as by brazing, to the housing 35 at one end of each of the bores 36 and slideably mounted at the other end of each of the bores 36 to allow for thermal expansion.

One end of the helix 37 is secured to the inner conductor 44 of a coaxial input terminal 45; the tube end at which the input terminal 45 is located will be referred to as the input end of the tube. The other end of the helix 37 is advantageously connected by a jumper lead 46 to one end of the helix 38, the jumper lead 46 extending through a bore or aperture 47 between the bores 36 in which the helices 37 and 38 are located. This bore or aperture 47 may be provided by drilling down from the end of the housing 35 or by drilling through from the side of the housing; in either case however, the undesired apertures are plugged so that only the bore or aperture 47 remains. Similarly the other end of the helix 38 is connected by a jumper lead 49 extending through an aperture or bore 50 to the one end of the helix 39. The other end of the helix 39 is connected to the inner conductor 51 of a coaxial output terminal 52, and the end of the tube at which the output terminal 52 is located shall be referred to as the output end. While it will facilitate the description of the specific embodiment depicted in Fig. 2 to refer to input and output ends, it is to be understood that the input and output terminals 45 and 52 could readily be at the same end of the tube if an even number of helices is employed.

Each end of the housing 35 is advantageously cup-shaped with slight depression in which are situated a plate 55 and a pair of insulator discs 56. Outer cup members 57 and 58 are secured, as by brazing, to the housing 35 and define with it the envelope of the traveling wave tube. A plurality of spring members 59 are advantageously secured, as by spot welding, to the inner walls of the envelope cup members 57 and 58 and position the plates 55 and discs 56 against the housing 35. The plate 55 at the input end of the tube advantageously has two apertures 61 therein aligned with the bores 36 in which are positioned helices 37 and 39. A plurality of fine wires 62 extend across the apertures 61 and define the accelerating electrodes of the electron gun systems for these two helices. A cathode assembly 64 is supported between the two insulator discs 56 adjacent the apertures 61 for projecting a stream of electrons along each of the helices 37 and 39, the cathode assembly 64 comprising a heater cup 65, a plate member 66 across the end of the heater cup 65 and advantageously having a cathodic material thereon, a heater element 67 within the heater cup 65, and a heat shield 68 having a flange portion 69 between the two insulator discs 56 and to which the heater cup 65 is secured by a plurality of struts 70.

At the output end the plate 55 is solid adjacent the other

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end of the helices 37 and 39 and defines the collector electrode therefor but has an aperture 71 therein adjacent the end of the helix 38. A plurality of fine wires 72 extend across the aperture 71 and define the accelerating electrode of the electron gun system for the helix 38, the electron gun system also comprising a cathode assembly 74 similar to the cathode assembly 64 and supported between the insulator discs 56 at the output end of the tube.

An axial bore 76 advantageously extends through the housing 36 and the heater leads 77 and cathode lead 78 for the cathode assembly 74 extend through the bore 76 and are connected at the input end of the tube to similar heater leads 80 and cathode leads 81 from the cathode assemblies 64 and to terminal leads 83 extending through a ceramic, such as glass, disc 85 sealed in the envelope cup member 57. Getters 86 are also advantageously supported by certain of the terminal leads 83. Thus in accordance with one aspect of this specific embodiment of this invention terminals for the electron gun assemblies need be provided at only one end of the tube, whereby the tube may be facily mounted, even through the cathode assemblies alternate between the opposite ends of the tube. An exhaust tubulation 88 is advantageously secured to the envelope cup member 58 at the output end of the tube to enable evacuation of the envelope of the tube.

While the mid-band frequencies of the helices 37, 38 and 39 may be varied by providing helices of either different pitch or different internal diameter, it facilitates the assembling of the tube if the bores 36 and the support rings 41 are all uniform, and thus advantageously the helices are provided with different pitches to attain the increased band width at optimum gain, in accordance with this invention.

In the embodiments of this invention depicted in Figs. 1, 2 and 3 a high gain was desired with the frequency band for optimum gain considerably increased in accordance with certain aspects of this invention. Turning now to Fig. 4 there is shown another specific illustrative embodiment of this invention wherein high power output is desired with the increased frequency region for optimum gain in accordance with this invention. As there seen a plurality of helices 90, such as four, are positioned within the envelope 91 of a traveling wave tube and connected in parallel, each helix 90 having a separate cathode 92 and accelerating electrode 93 for projecting a stream of electrons therethrough and to a common collector electrode 95. In accordance with this invention the helices 90 advantageously are wound at different mid-band frequencies, as described further above. Further the helices also advantageously are so designed as to have the same length measured in terms of wavelengths at a common frequency so that the phase shift at any frequency will be the same for all helices even though they have different mid-band frequencies. Thus partial or complete cancellation of the signal at certain frequencies due to different phase velocities of the helices and the vector addition of the output signals when applied to the common coaxial output terminal 97 will not occur.

At certain frequencies some helices exhibit a dispersion effect, the dispersion being the change of phase velocity with frequency. In the embodiment of Fig. 4 it is advantageous to employ helices having a substantially flat dispersion characteristic over a wide band of frequencies in the desired frequency range of operation. If for certain reasons this is not desirable, the dispersion can be corrected for by employing a phase equalizer between the end of the helix interaction circuit of the individual helix and the common output terminal. In the embodiment of Fig. 5, wherein like elements are numbered as in Fig. 4, three helices 100, 101 and 102 are connected in parallel and the phase equalization is provided by a few turns of the helices 101 and 102 themselves but positioned behind the individual collector electrodes 104 so that no inter-

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action with the electron beam can occur in the region of these turns.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A traveling wave tube comprising an envelope, a plurality of helices within said envelope having parallel axes, a conducting plate having a plurality of apertures therein adjacent the ends of said parallel positioned helices, a plurality of fine wires across each of said apertures, cathode means for projecting a stream of electrons through each of said apertures at one end of said helices and against the other of said plates at the other end of said helices, means electrically connecting said helices in series, the directions of said electron streams alternating along said series connected helices, means for applying an input signal to one of said helices, and means for removing an output signal from one end of another of said helices.

2. A traveling wave tube comprising a metallic housing having a plurality of parallel bores therein, a helix positioned in each of said bores, means electrically connecting said helices in series, cathode means at one end of said housing for projecting a stream of electrons along each of certain of said helices, cathode means at the opposite end of said housing for projecting a stream of electrons along the other of said helices, a conducting plate adjacent each end of said housing, said conducting plates having apertures therein between said cathode means and said helices, a plurality of fine wires across each of said apertures, said electron streams impinging on the portion of said conducting plate at the other end of said helices, means for applying an input signal to one end of one of said helices, means for removing an output signal from one end of another of said helices, and means for connecting all of the leads to said cathode means to one group of common terminals, said last-mentioned means including another bore through said housing and a plurality of leads extending through said bore.

3. A traveling wave tube comprising a metallic housing having a plurality of parallel bores therein, a helix positioned in each of said bores, the pitches of each of said helices being different whereby each of said helices has a different mid-band frequency for optimum gain, means electrically connecting said helices in series, a conducting plate having a plurality of apertures therein abutting each end of said housing, a plurality of fine wires across each of said apertures and defining an accelerating electrode, cathode means adjacent each of said apertures for projecting a stream of electrons along said helices, the direction of said streams alternating along said series connected helices, said electron streams impinging on the portion of said conducting plate adjacent said helix at the end opposite said cathode means, said portions defining electron collectors, means applying an input signal to the end of the first of said series connected helices adjacent said cathode means therefor, means for removing an output signal from the last of said series connected helices, and means connecting all of the leads from said cathode means to one group of common terminals, said last mentioned means including another bore through said housing and a plurality of leads extending through said bore.

4. A traveling wave tube comprising an envelope, a plurality of helices positioned in parallel in said envelope, each of said helices having a different mid-band frequency along its interaction region, means for projecting a distinct beam of electrons along each of said helices, means for applying an input signal to said helices, and means for removing an output signal from said helices.

5. A traveling wave tube adapted to amplify a broad-band signal comprising an envelope, a plurality of helices

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positioned in parallel in said envelope and directly electrically connected together, each of said helices having a different mid-band frequency along its interaction region, means for projecting a distinct beam of electrons along each of said helices, means for applying an input signal to said helices, and means for removing an output signal from said helices.

6. A traveling wave tube in accordance with claim 5 wherein said helices are electrically connected in series and the direction of said distinct electron beams alternates along said series connected helices.

7. A traveling wave tube in accordance with claim 5 wherein said helices are electrically connected in parallel and said input signal applying means includes means for applying said input signal to one end of each of the said helices in parallel.

8. A traveling wave tube in accordance with claim 7 further comprising electron collector means for each of said electron beams, said individual collector means being positioned at different distances along said helices from said input means, and phase equalization means within said envelope connected between certain of said helices adjacent said collector means therefor and said output

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means, said output means being common to all of said helices for removing the output signals from each of said helices.

9. A traveling wave tube in accordance with claim 8 wherein each of said phase equalization means comprises a portion of a helix associated therewith between said electron collector means and said output means.

10. A traveling wave tube in accordance with claim 5 wherein the pitch of each of said helices is different whereby the mid-band frequency for optimum gain is different for each of said helices.

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