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WIDEBAND AMPLIFIER UTILIZING COMMON ELECTRON BEAM FOR INTERACTION WITH HIGH-FREQUENCY TRAVELING-WAVE LINE AND WITH LOW-FREQUENCY ELECTRON MULTIPLIER

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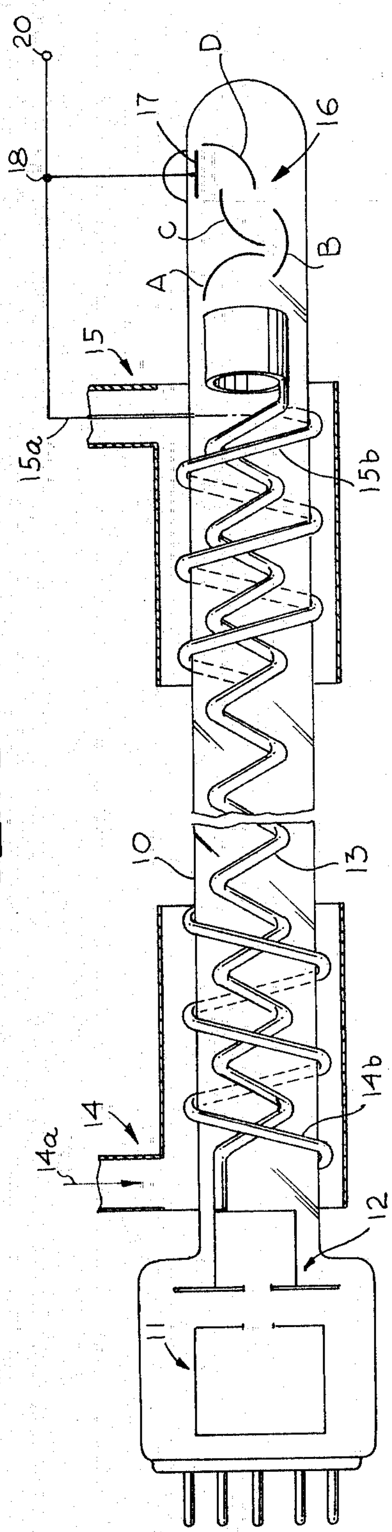

Fig. 1

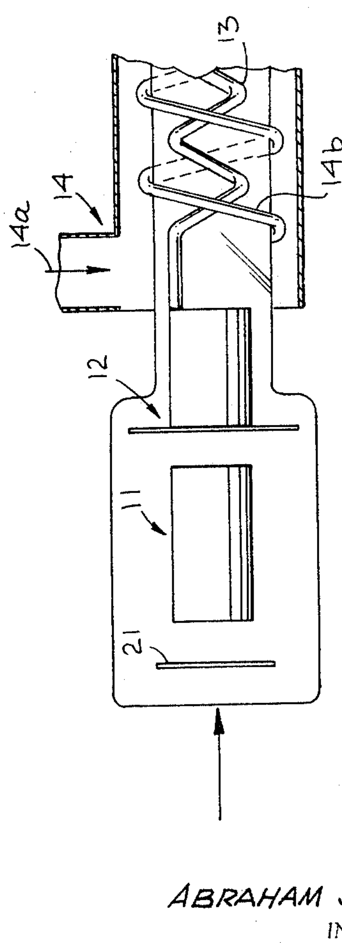

Fig. 2

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The present invention relates to an improved type of traveling-wave tube apparatus.

In the conventional traveling-wave tube, an electron gun produces a cathode-ray beam which is shot through a long closely-wound helix for collection at the other end by a pickup electrode at anode potential. An axial magnetic focusing field is provided to aid in maintaining the beam diameter small and to guide the beam through the center of the helix. The signal to be amplified is applied to the end of the helix adjacent to the electron gun and, under appropriate operating conditions, an amplified signal then appears at the other end of the helix.

More specifically, the input signal produces a wave that propagates along the helix with the production of a traveling axial electrostatic field inside the helix. The velocity with which this field travels corresponds to propagation around the turns of the helix at the velocity of light. The axial velocity is accordingly the velocity of light multiplied by the ratio of helix pitch to helix circumference. When the velocity of the electrons traveling through the helix is slightly but uncritically greater than the actual velocity of the wave on the helix, an interaction takes place between the moving axial electrostatic field of the helix wave and the moving electrons which is of such a character that, on the average, the electrons deliver energy to the wave or, stated differently, D.C. beam energy is transferred to the R.F. electric field. This causes the wave to become larger as it approaches the output end of the helix, resulting in amplification.

The traveling-wave tube gives amplification without resonance and, moreover, does so at an impedance level corresponding to that associated with such wideband devices as waveguides and coaxial lines. Accordingly, the traveling-wave tube is an inherently wideband device. However, for practical considerations, the bandwidth of traveling-wave tubes have not yet been extended to frequencies below a few hundred megacycles, simply because the wavelengths of the signals at these lower frequencies are such that the size of the traveling-wave tube must be increased to an impractical extent. As a result, it has been customary to use two separate and distinct channels whose outputs are combined, one channel operating on signals above a few hundred megacycles and the other operating on those below a few hundred megacycles. It is thus seen that there has been a long-felt need for an improved traveling-wave tube device whose operating bandwidth would extend down to substantially zero frequency without, at the same time, requiring that its size be unduly increased. This is especially true since the advent of the laser by means of which extremely wideband communications has been made possible. The present invention fulfills this need.

It is, therefore, an object of the present invention to provide a traveling-wave tube device capable of operating over much wider bandwidths than conventional tubes of this kind.

It is another object of the present invention to provide a traveling-wave tube device that will operate down to a frequency of about zero cycles per second.

It is a further object of the present invention to extend the operation of traveling-wave tubes down to frequencies well below a few hundred megacycles without, at the same time, requiring any material increase in its dimensions as compared to conventional traveling-wave tubes.

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 figures in 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.

FIGURE 1 illustrates traveling-wave tube apparatus constructed in accordance with the concept of the present invention;

FIGURE 2 illustrates a modified version of the FIG. 1 tube.

For a consideration of the invention in detail, reference is now made to the drawing wherein like or similar parts or elements are given like or similar designations in the figures. In FIG. 1, the embodiment is shown to include the tube envelope **10** in the front end of which is a conventional electron gun that produces an electron beam. The electron gun is generally designated **11** and in front of it is mounted an accelerating electrode, generally designated **12**, to which a suitable voltage is applied (not shown) for accelerating the electron beam forward into a slow-wave structure shown as a helical waveguide **13** which extends along a major portion of the tube. As is shown in the figure, the front and rear ends of helix **13** are electromagnetically coupled to input and output waveguide arrangements respectively designated **14** and **15**, the signal to be amplified being fed to the tube at input **14*a*** and, after amplification, being extracted at output **15*a***. The devices which couple the energy onto and off of helix **13** are special directional couplers which are in themselves helices respectively designated **14*b*** and **15*b***. These helices, which are outside of the vacuum envelope of the tube, are matched to the input and output coaxial transmission lines and capable of transferring the energy to and from the main helix inside the envelope without having to make contact with it.

Also mounted inside and at the very rear of envelope **10** is an electron-multiplier or dynode structure generally designated **16** whose function it is to multiply the electrons in the aforesaid beam by secondary emission. For this purpose, structure **16** illustratively includes a plurality of surfaces A, B, C and D which are progressively and increasingly positive with respect to each other. Briefly stated, secondary electrons produced on surface A are attracted toward surface B, and upon striking B produce still more electrons by secondary emission. These electrons are then attracted to surface C, with the production of secondary electrons, etc. Finally, adjacent dynode D and positioned to receive the electrons secondarily emitted from its surface is an anode **17** joined to output **15*a*** at junction point **18**, the combined outputs being fed by means of a common line to output terminal **20**.

In operation, the electron beam that is formed in gun **11** is amplitude-modulated by applying the lower bandwidth signals to the electrode that controls the beam current. In other words, by applying the previously-mentioned low-frequency signals to the electrode that controls the beam current, an electron beam is obtained that is intensity modulated in accordance with the amplitude variations of the signals applied to the electrode. At the same time, the higher bandwidth signals to be amplified are coupled by means of input arrangement **14** to the end of helix **13** nearest the electron gun and thereafter propagate along the helix in the same direction as the electron beam. As is well known, the velocity of the electrons is determined by the voltage difference between the cathode in the electron and the helix, and this is adjusted to give the electrons just the right velocity for interaction with the waves. Because of the interaction, the fields on the helix grow exponentially with distance and these amplified high-frequency waves are then coupled off of the helix at its farthest end by means of output arrangement **15**.

The electron beam passes through helix **13** and instead of being collected as it is in a conventional traveling-wave tube, it strikes the surfaces of dynodes A, B, C and D in succession. As a result, the number of electrons in the beam is very greatly increased, which means that a far stronger beam is ultimately received at anode **17**. Thus, in this way, the low-frequency signals originally used to modulate the beam are likewise considerably amplified. Both the low-frequency and the high-frequency signals are then fed to output terminal **20** as previously indicated.

By properly designing the traveling-wave portion of the tube, the low-frequency end of its frequency characteristic can be made to overlap the high-frequency end of the frequency characteristic for the electron multiplier portion of the tube, thereby providing an extremely wide bandwidth of operation, from practically D.C. to several thousand megacycles. However, an overlap of the kind described is not essential and may even be undesirable for some purposes. Thus, the traveling-wave section of the tube can be designed so that its frequency characteristic lies well above that for the dynode structure and, by so doing, two separate and distinct or isolated bandwidths of operation are obtained for the same tube. In consequence thereof, two different modulated carriers can now be passed through the same traveling-wave tube, the two carriers differing very widely in frequency.

As is shown in FIG. 2, the FIG. 1 embodiment may be modified to adapt it for use with modulated light beams. For this purpose, electron gun **11** is modified to include a photo-sensitive surface or element **21** of the same kind that would be used in a photo-multiplier tube. More particularly, the heater-type of cathode found in the electron gun structure of FIG. 1 is replaced with a photocathode, namely, element **21**, in the electron gun structure of FIG. 2. Consequently, in response to either an unmodulated or modulated light beam that is incident upon it, photocathode **21** emits a corresponding electron beam which, as before, is accelerated by electrode **12** into the axial region of helix **13**. The remaining operation is as previously described in connection with the FIG. 1 device and, therefore, is not repeated here to avoid being unnecessarily redundant.

Although only a couple of arrangements of the invention have been illustrated above by way of example, it is not intended that the invention be limited thereto. Accordingly, the invention should be considered to include any and all modifications, alterations or equivalent arrangements falling within the scope of the annexed claims.

Having thus described the invention, what is claimed is:

1. Amplifier apparatus comprising: a single envelope in which are mounted a traveling-wave tube structure in the forward section of said envelope; a dynode structure in the rearward section of said envelope; means for projecting an electron beam to interact with said traveling-wave structure and said dynode structure, respectively; and means, forming the output of said dynode structure, for collecting said electron beam; said traveling-wave and dynode structures being connected together at their output ends forming a single composite output, whereby a signal to be amplified is divided into two components, a high-frequency component to be amplified by said traveling-wave structure, and a low frequency component to be amplified by said dynode structure.

2. The apparatus defined in claim **1** wherein said traveling-wave tube structure is constructed to provide a frequency characteristic that overlaps the frequency characteristic of said dynode structure.

3. The apparatus defined in claim **1** wherein said traveling-wave and dynode structures are constructed to respectively provide non-overlapping frequency characteristics.

4. Amplifier apparatus: a single envelope in which are mounted a traveling-wave tube structure in the forward section; an electron-multiplier structure in the rearward section; means for projecting an amplitude-modulated electron beam to interact with said traveling-wave structure and said electron-multiplier structure, respectively; and means, forming the output of said electron-multiplier structure, for collecting said electron beam; said traveling-wave and electron-multiplier structures being connected together at their output ends forming a single composite output, whereby a signal to be amplified is divided into two components, a high-frequency component to be amplified by said traveling-wave structure, and a low-frequency component to be amplified by said electron-multiplier structure.

5. The apparatus defined in claim **4** wherein said electron-beam projecting means includes a photo-sensitive element mounted at the front of said envelope for producing said modulated electron beam in response to a modulated light beam incident thereon.

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