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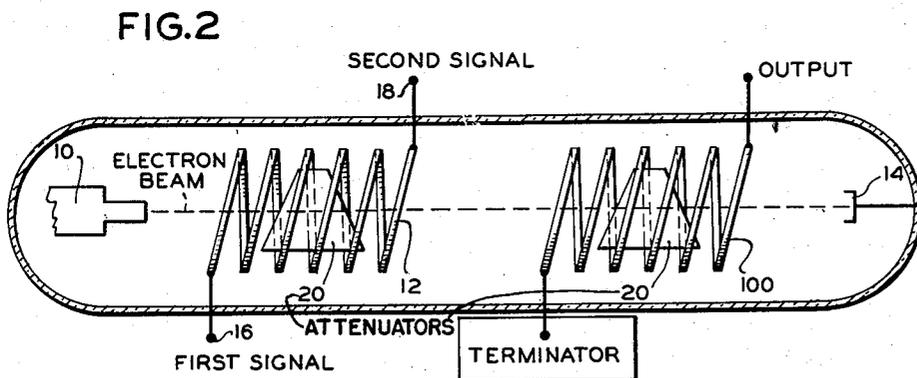
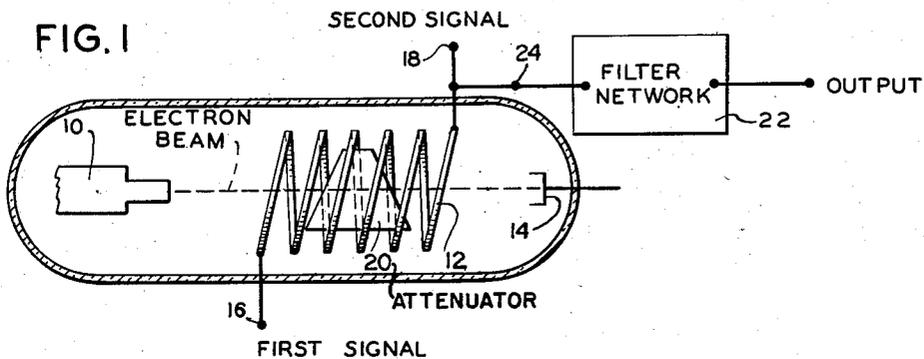
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TRAVELLING WAVE TUBE MIXER

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2 Sheets-Sheet 1



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FIG. 3

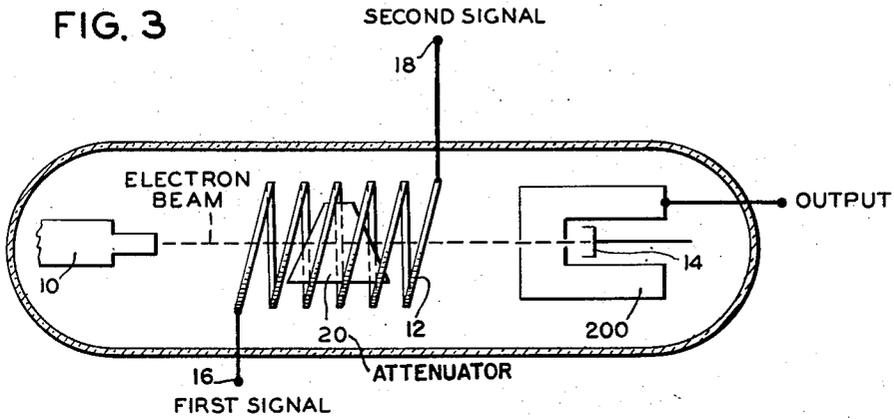
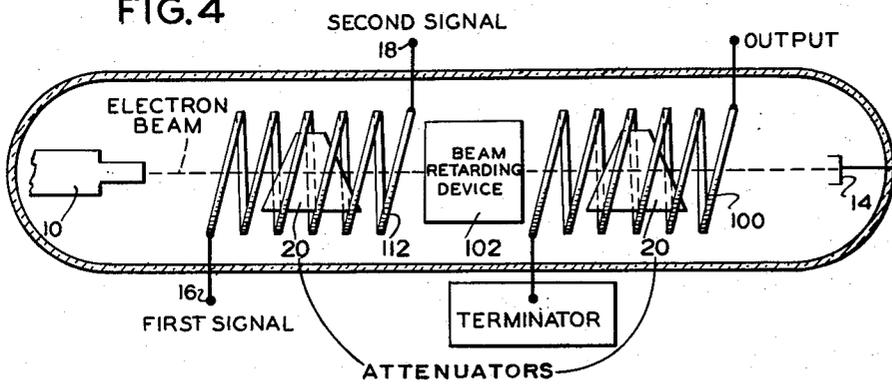


FIG. 4



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TRAVELLING WAVE TUBE MIXER

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1 Claim. (Cl. 250—20)

My invention relates to improved travelling wave tubes. In the conventional travelling wave tube, an electron beam is passed through a slow microwave structure, such as a helical waveguide, in a direction parallel to the axis of the guide and is thereafter collected at a beam collection electrode. A microwave signal whose frequency falls within a given frequency band is supplied at the end of the helix adjacent the electron gun and appears in amplified form at the other end of the helix. The amplification is obtained by adjusting the velocity of signal propagation along the waveguide in the axial direction (the synchronous velocity) to be approximately equal to the velocity of the beam. Due to the electromagnetic interaction of the guide and the beam, power is transferred from the beam to the guide to provide the desired amplification. This conventional structure can be modified in such manner that the tube can be used as an oscillator or as a limiter.

Recent advances in the microwave art have made it desirable to utilize a travelling wave tube as a microwave mixer; for example, such a mixer could be used in mixing two signals differing in frequency to extract an output signal whose frequency is equal to the difference between the frequencies of the incoming signals.

I have succeeded in developing a travelling wave tube structure which can be used for this purpose.

Accordingly it is one object of the present invention to modify a travelling wave tube structure in a novel manner so as to permit its use as a microwave mixer.

Another object is to provide a new and improved travelling wave tube microwave mixer.

Still another object is to provide a new and improved travelling wave tube in which two incoming microwave signals having different frequencies can be mixed together to produce a plurality of signal components having frequencies which differ from each other and also differ from the frequencies of the incoming signals.

Yet another object is to improve travelling wave tube mixers in such manner that an output signal having a frequency differing from the frequencies of the two incoming signals can be extracted from signal components carried by the beam or by the helix.

These and other objects of my invention will either be explained or will become apparent hereinafter.

In my invention there is provided a travelling wave tube wherein an electron beam is constrained to flow within a slow wave structure, such as a helical waveguide, in a direction parallel to the axis of the guide and thereafter collected at a collection electrode. First and second microwave signals having different frequencies are respectively supplied to first and second axially displaced points on the guide. As a result an electromagnetic field established by these signals within the guide interacts with the beam to mix the first and second signals together and produce first and second sets of signal components having different frequencies which also differ from the signal frequencies. The first set of components is carried primarily by the beam. The second

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set is carried primarily by the guide. The component frequencies, for example, can include frequencies equal to the sum or difference of the frequencies of the first and second signals, or can be equal to or a harmonic of the product of the two signal frequencies.

A frequency selector is positioned adjacent the guide in a location intermediate the first point and the collection electrode. This selector is responsive to a selected one of the component sets to extract therefrom at least one of the components. For example, this selector can be coupled to the helix and therefore be responsive to the second set of components.

Alternatively, the selector can be positioned in the path of the beam intermediate the guide and the collection electrode and in this case can be coupled to the beam and responsive to the first set of components. In the latter case, the selector can comprise a second slow wave structure (as for example a second helical waveguide) in which case the device is effective over a wide range of frequencies. As a further example, the selector can comprise a resonant cavity, in which case the selector is effective over a narrow selective frequency range.

My invention will now be described in detail with reference to the accompanying drawings wherein

Fig. 1 shows one illustrative embodiment of my invention;

Fig. 2 is a second illustrative embodiment;

Fig. 3 is a third illustrative embodiment; and

Fig. 4 is a fourth illustrative embodiment.

Referring now to Fig. 1, an electron gun 10 produces an electron beam which passes within a slow wave structure shown as a helical waveguide 12 in a direction parallel to the axial direction thereof and is thereafter collected at a collector electrode 14. A first incoming microwave signal having a first frequency is applied at terminal 16 of the waveguide. A second microwave signal having a second frequency is applied at terminal 18 of the waveguide and an attenuator 20 is positioned within the helix at a point intermediate terminals 16 and 18. The velocity of the beam and the velocity of signal propagation along an axial direction of the helical waveguide (the synchronous velocity) are adjusted to be substantially identical.

There is also provided a microwave filter network 22 coupled at its input to terminal 24. Terminal 24 is connected to terminal 18. Conventional magnetic focussing means (not shown) are normally mounted about the helical axis to focus and constrain the beam and prevent its spreading as it passes through the helix.

With the exception of the filter network 22 and the second signal input terminal 18, the above arrangement is a conventional travelling wave tube structure and therefore exhibits a characteristic input power-output power relationship which for low level signals is linear, i.e., as the input power increases by a given percentage, the output power increases by approximately the same percentage. For high level signals, however, the tube approaches saturation and the output power will not increase appreciably, as the input power increases. At this point, the tube operates in a non-linear manner. Thus, when the power level of the first signal appearing at terminal 16 is low, and no signal is applied to terminal 18 therefore, this arrangement will function as a linear amplifier; the first signal will travel along the guide from terminal 16 toward terminal 18 and will be amplified in conventional manner. However, when a second signal is present, it will travel from terminal 18 toward the attenuator and then will be reflected back toward terminal 18. If the power levels of the first signal and the second signal are properly adjusted, the combined power level will be such as to cause non-linear operation of the tube. Since the first and second signals differ in fre-

quency, the non-linear operation produces a mixing action.

It can be shown, through the use of conventional techniques, that this mixing action produces a plurality of signal components having frequencies which differ from each other and yet from the signal frequencies. For example, one such signal component can have a frequency equal to the sum of the two signal frequencies; another component can have a frequency equal to the difference between the two signal frequencies; and a third component can have a frequency equal to the product of the signal frequencies; other components can have frequencies which are harmonically related to the other signal component frequencies.

Depending upon the bandwidth characteristics of the helix and also upon the characteristic of the beam, one set of the signal components will be carried primarily by the beam, while a second set will be carried primarily by the helix. Stated differently, when the device is operated in a non-linear fashion as previously described, the electromagnetic field within the waveguide interacts with the beam to produce the mixing action, and the signal components thus produced are carried in part by the beam and in part by the helix. When the helix has a bandwidth which can accommodate a frequency equal to the difference in the signal frequencies, and is insufficient to carry a frequency equal to the sum of the frequencies, the difference frequency will be carried primarily by the helix and will appear at terminal 24. The filter network is adjusted to pass this different frequency and to reject all others. As a result, the frequency of the signal component appearing at the output of the filter network is equal to this different frequency. When for example, a second microwave signal is supplied from a local oscillator, it will be seen that the arrangement in Fig. 1 functions as a mixer to produce an intermediate frequency signal.

The arrangement in Fig. 2 differs from that shown in Fig. 1 in that network 22 is no longer used and instead a second helical guide 100 is interposed between the helical guide 12 and the collector electrode 16 in the path of the electron beam. (The synchronous velocity of guides 100 and 12 are substantially identical.) The second helical guide can also extract the intermediate frequency signal in the same manner as the arrangement shown in Fig. 1. In Fig. 2, however, the intermediate frequency signal will be extracted from the electron beam rather than from the helix as shown in Fig. 1.

Fig. 3 shows an arrangement similar to Fig. 2, except that the second helical guide 100 is replaced by a resonant cavity 200. The systems shown in Figs. 2 and 3 function in the same fashion except that a resonant cavity has an inherently narrow bandwidth, while a helical guide has a much wider bandwidth.

In the embodiment of Fig. 2, both waveguides have the same synchronous velocity. However, when the two incoming signals have frequencies falling in the K band, for example, and when the intermediate frequency to be extracted falls, for example, within the S band, the structure can be modified as shown in Fig. 4. Here a conventional optical beam retarding device 10 for reducing the beam velocity is interposed between waveguides 100 and 12, and the waveguide 100 has a synchronous velocity which is approximately equal to the reduced beam velocity. Hence, the synchronous velocity of waveguide 100 is lower than that of waveguide 12.

The beam retarding device is of conventional type and need not be described in detail here. Further details on such a device can be found, for example, in a Stanford University publication, "Electronics Research Laboratory Technical Report #35," published on May 31, 1951 and in "Proceedings of the IRE" (vol. 40, June 1952, pp. 688-695), "Space-Charge Waves in an Accelerated Electron Stream for Amplification of Microwave Signals." The authors of both articles are Ping King Tien and Lester M. Field.

This arrangement has certain inherent advantages. For example, the synchronous velocity of waveguide 12 must be relatively high in order to prevent the physical structure from becoming excessively small. If waveguide 100 is to have the same synchronous velocity, its radius will have to be large relative to the radius of waveguide 12, because the frequencies carried by waveguide 100 are much smaller than the frequencies carried by waveguide 12. Consequently, the small diameter beam emerging from waveguide 12 will not sufficiently interact with the electromagnetic field within waveguide 100 to produce satisfactory output power.

Therefore the radius of waveguide must be decreased, thereby increasing the interaction and the output power. However, in order to maintain the synchronous velocity in waveguide 100 independent of frequency over the band of frequencies of interest the number of turns per inch of waveguide 100 must be increased. As a consequence, the synchronous velocity of waveguide 100 is decreased. Therefore, for proper interaction, the velocity of the beam as it emerges from waveguide 12 must be reduced before it enters waveguide 100; the beam retarding device 102 acts to reduce the beam velocity in the manner desired.

Alternatively, the magnetic focusing field can be adjusted to permit the beam to spread within waveguide 100 and this increases the interaction without reducing the radius of waveguide 100.

In the embodiment shown, I have employed a lumped attenuator 20. As is well known in the art, the slow wave structure can be designed to have sufficient distributed attenuation so as to eliminate the need for a lumped attenuator. My invention contemplates the use of either type of attenuator arrangement.

It will be apparent to those skilled in the art that one or more additional signals can be applied to corresponding one or more points axially displaced along the slow wave structure 12, and that all such additional signals will be mixed with the first and second signals in the manner previously described.

While I have pointed out and shown my invention as applied above, it will be apparent to those skilled in the art that many modifications can be made within the scope and sphere of my invention as defined in the claim which follows.

What is claimed is:

In a travelling wave tube wherein an electron beam is constrained to pass through a first slow wave structure and is thereafter collected at a collector electrode; means to respectively supply first and second microwave signals having different frequencies to first and second axially displaced points on said first slow wave structure whereby an electromagnetic field is established within said first structure, said field interacting with said beam to mix said first and second signals together to produce first and second sets of signal components having different frequencies which also differ from said signal frequencies, said first set being carried primarily by said beam, said second set being carried primarily by said first slow wave structure; a second slow wave structure positioned intermediate said first slow wave structure and said electrode in the path of said beam, said second slow wave structure extracting at least one signal component from said first set of components; a beam retarding device interposed between said first and second structures in the path of said beam, the beam velocity as it passes through the first structure being approximately equal to the synchronous velocity of signal propagation established within said first slow wave structure, said second slow wave structure establishing a different and lower synchronous velocity of signal propagation, said retarding device reducing the velocity of said beam as it enters the second slow wave structure to a point at which

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said reduced velocity is substantially equal to said lower synchronous velocity.

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