Oct. 11, 1960 H. B. BRISKIN 2,956,199

FREQUENCY DISCRIMINATOR

Filed July 24, 1958

Fig. 1

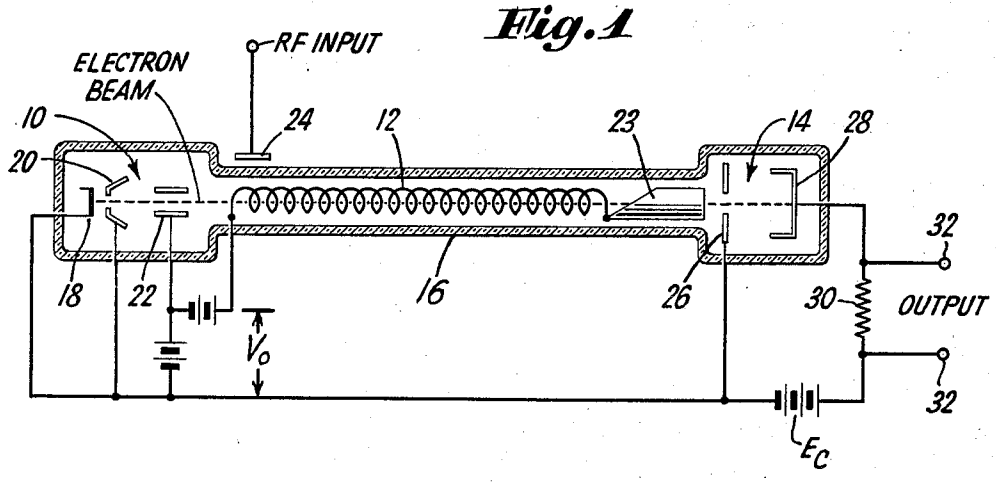
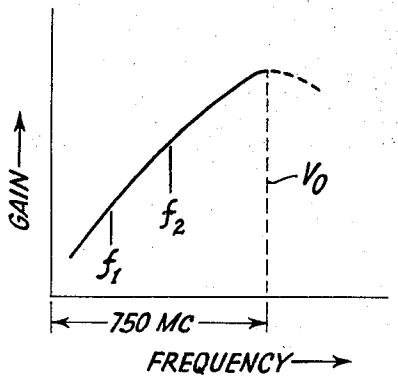



Fig. 2




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# FREQUENCY DISCRIMINATOR

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My invention relates to improved traveling wave tubes.

There are various applications in the microwave art requiring a device which functions as a frequency discriminator over a wide frequency range, for example, 750–1000 megacycles. An additional requirement is that such device be capable of producing an output signal in response to an input signal of any frequency within the frequency range received, without the necessity for a tuning operation. Further, the inherent noise level of such a discriminator must be low enough so that it does not seriously interfere with the readability of output indications of low level signals. A final requirement is that the device must not saturate at the higher output levels.

Accordingly, it is an object of this invention to produce a new and improved broad band microwave frequency discriminator having the above advantages.

Another object is to provide a new and improved traveling wave tube capable of producing a frequency discriminating action.

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

In accordance with the principles of my invention, I provide means for producing an electron beam, a velocity sorting detector positioned in the path of said beam and separated from said beam producing means, and a dispersive helical slow wave structure interposed in the path of the electron beam between the beam producing means and the velocity sorting detector.

The beam producing means projects an electron beam into the space within the slow wave structure at a certain velocity (synchronous velocity) depending upon the value of the voltage applied to the helix. The slow wave structure has a characteristic such that when a signal having a variable frequency is applied to its input end, an electromagnetic field is propagated along the length of the helix at a phase velocity which varies as the signal frequency varies. This electromagnetic field interacts with the electron beam, thereby velocity modulating the electron beam. The velocity detector then derives from the velocity modulated beam an output signal having an amplitude proportional to the amount of interaction between the electromagnetic field and the electron beam and also proportional to the input frequency. Thus, a microwave frequency discriminator is produced which is capable of operating over a broad range of frequencies.

An illustrative embodiment of my invention will now be described in detail with reference to the accompanying drawings wherein:

Fig. 1 shows a traveling wave type tube constructed in accordance with one embodiment of the invention; and

Fig. 2 shows a graph of gain versus frequency for the device shown in Fig. 1.

Referring now to Fig. 1, there is shown a traveling wave tube comprising an electron gun **10**, a dispersive helical slow wave structure **12** and a velocity sorting detector **14**, all contained within an evacuated glass envelope **16**.



The electron gun is similar to that employed in conventional traveling wave tube amplifiers, having a cathode **18** and beam forming electrodes **20** and **22** and having impressed thereon the proper potentials for producing the desired electron beam.

The slow wave structure **12** is positioned with respect to the gun **10** so that the electron beam travels along the axis of the structure. The beam is compressed and thus confined within the structure by a magnetic field, not shown.

The slow wave structure comprises a helix which is dispersive and is provided with a termination **23** to absorb the radio frequency energy on the helix in order to prevent reflections. A dispersive helical slow wave structure is one so designed that when a fixed voltage is applied to the helix, the phase velocity of a wave traveling along the helix varies as the frequency varies, as distinguished from a non-dispersive helix wherein the phase velocity is independent of frequency. A dispersive helix such as is used in forward type traveling wave tube amplifiers that are dispersive has the desired characteristics. A discussion of the design of such a helix can be found at page 118 in a paper entitled "Operation of the Traveling-Wave Tube in the Dispersive Region," by L. A. Roberts and S. F. Kaisel, published in "Convention Record of the I.R.E." part 6, 1953, pages 118–122.

A potential having a value $+V_0$ with respect to the the cathode **18** is applied to the helix **12**. For a given dispersive helical slow wave structure the value of $V_0$ determines the frequency at which maximum gain of the tube is achieved, as can be seen from the curve of Fig. 2. This curve shows the manner in which the gain of the tube varies as the frequency of the input signal to the helix varies. By utilizing the solid portion of the curve, each different frequency, within the range covered by the tube, will produce a different value of potential at the output of the tube.

A microwave RF input signal is coupled to one end of the slow wave structure **12** at a point **24**. The signal may be introduced by any known satisfactory technique including, for example, a coaxial cable. The signal so introduced is constant in amplitude but variable in frequency. This signal produces an electromagnetic field or wave on the slow wave structure which interacts with the electron beam in the region of the structure, velocity modulating the beam by a variable amount depending upon the frequency of the input signal.

The velocity sorting detector **14** includes an apertured electrode **26**, disposed in the path of the electron beam and a collector electrode **28** also positioned in the path of the electron beam. Included further as a part of the detector is a resistor **30** connected between the collector **28** and a source of positive potential $E_c$ for the collector. The apertured electrode **26** may be connected to cathode potential as shown, or it may be biased at some potential slightly more negative than the cathode potential. In any event, the apertured electrode **26** so connected acts as a gate to allow only those electrons which exceed certain predetermined minimum velocities to travel through the aperture in the apertured electrode and thus to impinge the collector **28**. These electrons flow through the resistor **30**, thus producing a potential at the output terminals **32**.

The device operates in the following manner:

The electron beam produced by the gun **10** is projected into the region within the helix toward the collector electrode **28**. The beam enters the helix having a certain synchronous velocity depending upon the value of the voltage $V_0$ applied to the helix.

When a signal of a certain frequency $f_1$, see Fig. 2, is applied to the helix at the input **24**, an electromagnetic

field or wave is propagated along the helix at a certain phase velocity $v_1$. This wave interacts with the electron beam, velocity modulating the beam. As the beam is modulated, some of the electrons are given an increased velocity and some a decreased velocity. As the beam approaches the apertured electrode **26**, this electrode, which is at cathode potential, causes a velocity sorting action to take place. The number of electrons which can pass through the apertured electrode to strike the collector **28** is determined by the number of electrons having a velocity greater than a predetermined minimum velocity. The electrons impinging the collector flow in the collector circuit, producing a certain potential $V_1$ across the resistor **30**. The electrons having too low a velocity to pass through the apertured electrode will be repelled by that electrode and attracted to the helix, since it is connected to a positive potential.

If an input signal having a greater frequency $f_2$, Fig. 2, is applied to this input of the helix, the electromagnetic wave now travels along the helix at a higher phase velocity $v_2$. This wave will produce a greater degree of interaction with the electron beam than when $f_1$ was applied, thus imparting a velocity greater than the predetermined minimum velocity to more electrons in the beam. Therefore, the number of electrons passing through the apertured electrode and reaching the collector will be increased and will produce an increased potential $V_2$ across the output resistor **30**. It can thus be seen that for each different frequency applied to the input of the helix, a different potential will result across the resistor **30**; in other words, a frequency discriminating action is produced. This is clearly depicted by the curve of Fig. 2 wherein the potential is shown on the ordinate as a gain produced in the tube.

While I have shown the output potential developed across the resistor **30** located in the collector circuit, satisfactory results can also be achieved by developing the output potential across this resistor when connected in series with the apertured electrode.

What is claimed is:

1. A frequency discriminator comprising an electron gun having a cathode; a collector electrode separated from said electron gun, said collector electrode and said electron gun defining a path for electron flow; a dispersive slow wave structure surrounding said path, said slow wave structure being positioned between said electron gun and said collector electrode; means for coupling an input signal to said slow wave structure; an apertured electrode surrounding said path positioned between said dispersive slow wave structure and said collector electrode, said apertured electrode being maintained at a potential not greater than the potential applied to said cathode; and an output resistor coupled between said collector electrode and said cathode, said collector electrode being maintained at a positive potential with respect to said cathode, said frequency discriminator providing a voltage across said output resistor having a magnitude proportional to the frequency of said applied input signal.



2. A frequency discriminator as defined in claim 1 wherein said dispersive slow wave structure is in the form of a helix.

3. A frequency discriminator comprising an evacuated envelope; an electron gun having a cathode located at one end of said envelope; a collector electrode located at the other end of said envelope, said collector electrode and said electron gun defining a path for electron flow; a dispersive slow wave structure surrounding said path, said slow wave structure being positioned between said electron gun and said collector electrode; means for coupling an input signal to said slow wave structure; an apertured electrode surrounding said path positioned between said slow wave structure and said collector electrode; an output resistor and a direct voltage source connected in series between said apertured electrode and said collector electrode, said direct voltage source maintaining said collector electrode at a positive potential with respect to said apertured electrode, and means coupling said cathode to the negative terminal of said direct voltage source, said frequency discriminator providing a voltage across said output resistor having a magnitude proportional to the frequency of said applied input signal.

4. A frequency discriminator comprising an evacuated envelope having a longitudinal axis; an electron gun having a cathode located at one end of said envelope; a collector electrode located at the other end of said envelope, said collector and said electron gun defining a path for electron flow along the longitudinal axis of said envelope; a dispersive helical slow wave structure surrounding said path, said slow wave structure being positioned between said electron gun and said collector electrode; an apertured electrode having a centrally located aperture coaxial with said longitudinal axis, said apertured electrode being positioned between said slow wave structure and said collector electrode, the space between said apertured electrode and said collector electrode comprising an evacuated region; means for coupling an input signal to the end of said slow wave structure adjacent said electron gun; means for maintaining said slow wave structure at a positive potential with respect to said cathode; means for maintaining said apertured electrode at a potential not greater than that of said cathode; an output resistor coupled between said collector electrode and said cathode; and means for maintaining said collector electrode at a positive potential with respect to said cathode, said frequency discriminator providing a voltage across said output resistor having a magnitude proportional to the frequency of said applied input signal.

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