Aug. 22, 1967 H. F. CHAPELL 3,337,765

TRAVELING WAVE TUBE TIME DELAY DEVICE

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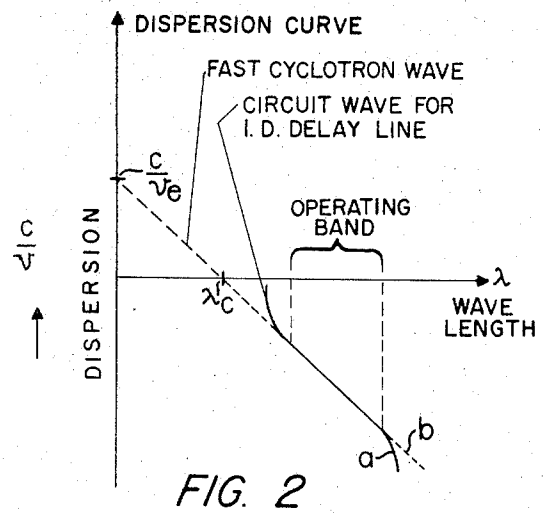


FIG. 2

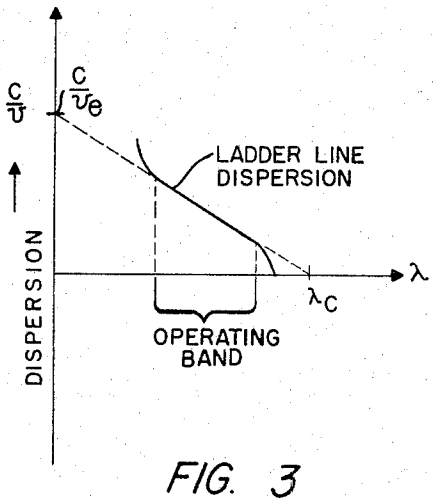


FIG. 3

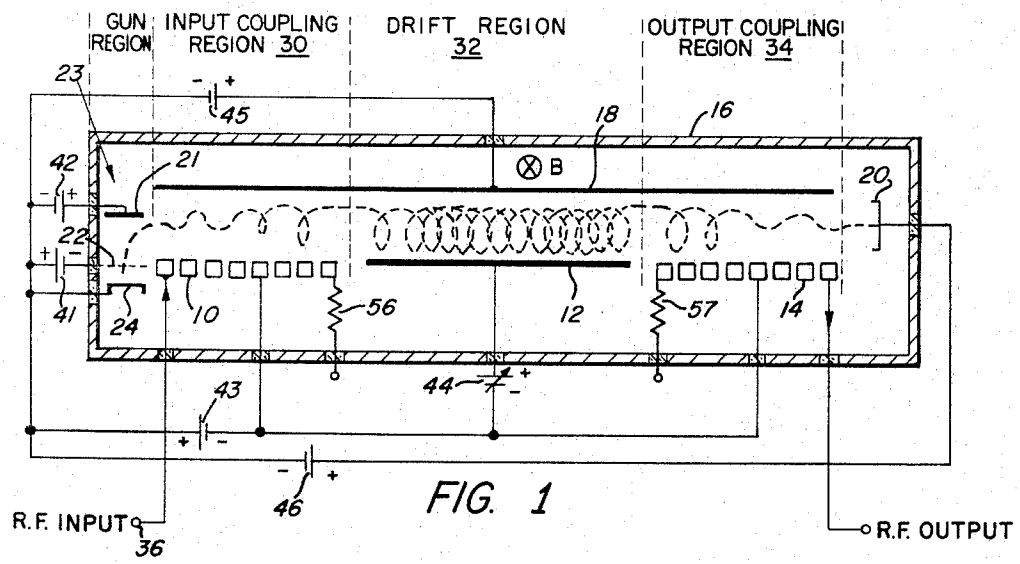


FIG. 1

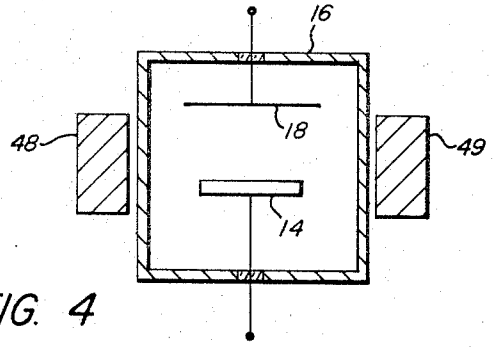


FIG. 4

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TRAVELING WAVE TUBE TIME DELAY DEVICE

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ABSTRACT OF THE DISCLOSURE

A variable time delay device for electromagnetic energy is disclosed comprising a slow wave delay line structure coupling energy into a crossed electric and magnetic field drift space region with a similar slow wave coupling structure disposed at the output end of the device. Variable control of the electric and magnetic fields in the drift space region has resulted in substantial time delays over an extremely wide bandwidth. The electromagnetic energy to be time delayed is coupled throughout the drift space region to the cyclotron beam wave.

This invention relates to electron discharge devices and more particularly to traveling wave tube devices for providing an electrically controllable time delay between an input and output signal.

Traveling wave tubes comprise in general a class of devices in which a beam of electrons emanating from a source such as an electron gun is compelled past a wave propagating structure upon which a radio frequency wave is either induced or propagated. Interaction occurs between the wave and the beam resulting in either oscillations or amplification, depending on the relative velocity of the waves and the beam. This invention is concerned with the M-type traveling wave tube as contrasted to the O-type or linear traveling wave tube. In the M-type tubes conversion of beam energy to radio frequency energy takes place in an interaction space having orthogonal direct current electric and magnetic fields, hence the term "M-type" or crossed-field device.

In such crossed-field devices, the magnetic field is not purely a focusing agent but is essential to the dynamics of the electron stream. Thus, electrons emitted from the electron gun travel in a cycloidal path because of the combined influence of the cross-electric and magnetic direct current fields in the interaction space. In the process of traveling in a cycloidal path the electrons interact with radio frequency fields in the interaction space converting potential energy of the beam electrons to radio frequency energy.

In the past the above described interaction phenomena has been employed to provide amplification of the radio frequency energy or to provide a radio frequency oscillator. In the device of the present invention amplification or oscillation of radio frequency energy is either incidental or suppressed.

In the apparatus of the invention, radio frequency energy is time delayed by coupling it from a broad band slow wave circuit, such as an interdigital delay line, into a cyclotron beam wave in a drift section. The time delay caused by cycloiding a beam can be understood by considering the motion of a single electron in a crossed-electric and magnetic field. This motion consists of (1), a uniform translation at a velocity v_m equal to the ratio of the electric field strength E and the magnetic field strength B, and (2), a motion in a circle with a radius r equal to the ratio of the difference between the beam initial electron velocity v_o and the uniform translation velocity v_m divided by ω_c, the cyclotron frequency.

The time delay t is equal to the length of the drift section L divided by the uniform translation velocity

v_m, that is, $t=L/v_m$. Since $v_m=E/B$ it can be seen that $t=LB/E$ and that the time delay can be electrically controlled by changing either the electric field strength or the magnetic field strength.

In the apparatus of the present invention a truly broadband time delay device is obtained by utilizing a slow wave circuit for coupling the radio frequency energy to be delayed into the beam. The slow wave structure is dispersive, that is, the phase velocity of the slow wave coupling structure is substantially equal to or in synchronism with the phase velocity of the cyclotron beam wave over a considerable frequency range. Hence, radio frequency energy throughout the whole range of synchronism is coupled into the cyclotron beam wave and is time delayed.

Other objects, features and advantages of the invention may be best considered from the following description taken in connection with FIGS. 1–3 wherein:

FIG. 1 is a schematic representation of a preferred form of the traveling wave electron time delay device of the present invention;

FIG. 2 is a graph of the dispersion characteristics of an interdigital delay line structure;

FIG. 3 is a graph of the dispersion characteristics of a ladder line delay structure; and

FIG. 4 is a transverse side-sectional view of the tube in FIG. 1 showing the magnetic pole pieces **48** and **49** for supplying the transverse magnetic field.

Referring now particularly to FIG. 1, one form of the traveling wave electron time delay device of the present invention is shown as comprising an input slow wave coupling structure **10** such as an interdigital delay line, a drift sole electrode **12**, and an output slow wave coupling structure **14**, each adjacent a common anode electrode **18** and defining three interaction spaces therebetween, an input coupling interaction region **30**, a drift region **32** and an output coupling interaction region **34** in that order progressing from electron gun **23**.

An electron gun **23** including a cathode **24**, a grid member **22** and accelerating anode **21**, projects a beam of electrons into interaction region **30**. Grid electrode **22** is suitably biased with respect to cathode **24** by means of voltage source **41**. Accelerating anode **21** is maintained at a positive potential with respect to cathode **24** by means of voltage source **42**. Anode electrode **18** and collector electrode **20** are maintained at a positive potential with respect to cathode **24** by means of voltage sources **45** and **46**, respectively.

Delay lines **10** and **14** are maintained at a negative potential by means of voltage source **43**, whereas sole electrode **12** is maintained at a negative potential by means of voltage sources **43** and **44**.

All electrode elements are contained within an evacuated envelope **16** which may comprise, for example, glass or other suitable material. A uniform magnetic field, represented by the symbol ⊗B to indicate that the direction of the magnetic field is perpendicular to the plane of the paper and directed into the plane of the paper, is supplied from a magnet or other suitable means. The magnetic field B is transverse the direction of beam flow and orthogonal to the electric field in the interaction regions.

In operation, radio frequency energy is coupled to input terminal **36** and propagates along interdigital delay line structure **10**, interacting with the cyclotron beam wave when synchronism exists betwen the two waves. FIG. 2 shows the synchronism condition for an interdigital delay line. FIG. 2 is a plot of dispersion, that is, the ratio of the speed of light c to phase velocity v of the circuit wave (solid line curve a) and fast cyclotron beam wave (dotted line curve b) versus wavelength.

From an analysis of FIG. 2 it can readily be seen that

interaction or coupling from the radio frequency input circuit wave to the cyclotron wave occurs throughout an extended frequency range contributing to the broad band frequency characteristics of the apparatus of the present invention.

Once the radio frequency signal is coupled into the beam it progresses on the beam in the form of modulations on the fast cyclotron beam wave and enters the drift region **32** formed by anode **18** and sole electrode **12**. Any circuit wave energy on line **10** is ultimately dissipated in lossy material **56** which serves as a matched terminating impedance for delay line **19**.

In drift region **32** the cyclotron beam wave is subjected to cross magnetic and electric fields resulting in a time delay of the beam wave proportional to the length of the drift region times the magnetic field strength B divided by the electric field strength E.

This time delay may be conveniently varied by adjusting the voltage supplied from variable voltage source **44**.

After the beam wave has been time delayed in drift region **32**, the beam passes through output coupling region **34** wherein the reverse of the process which occurred in region **30** occurs and the time delayed radio frequency signal is extracted from the beam through interaction of the fast cyclotron wave on the beam with delay line structure **14**.

It should be noted that in the apparatus described in connection with FIGS. 1 and 2, the cyclotron wavelength λc of curve *b* was chosen to be less than the operating wavelength λ, in which case an interdigital delay line was chosen for synchronous coupling. If λc is made greater than λ, a forward wave structure may be utilized such as a center ridge loaded ladder line which has a dispersion curve as shown in FIG. 3, curve *a*.

It is to be understood that the specific embodiments described are merely illustrative of the general principles of the invention. Various other structural arrangements and modifications may be devised in the light of this disclosure by one skilled in the art without departing from the spirit and scope of this invention.

What is claimed is:

In combination:

an electron gun for forming and projecting a beam of electrons;

means for supplying a magnetic field transverse the direction of beam flow;

an anode electrode disposed along the length of the beam;

a first slow wave structure adjacent said anode and nearest said electron gun for coupling radio frequency energy into the fast cyclotron wave on said beam and for establishing a D.C. potential orthogonal said magnetic field;

a second slow wave structure adjacent said anode and furthest removed from said electron gun for coupling radio frequency energy from the beam to the structure;

a sole electrode adjacent said anode intermediate to said first and second slow wave structures to define a drift space region and means for providing a variable voltage source in said drift space region to thereby time delay the radio frequency signal coupled into the beam.

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