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VARIABLE TIME DELAY ELECTRONIC APPARATUS

Filed Sept. 20, 1944

FIG. 1

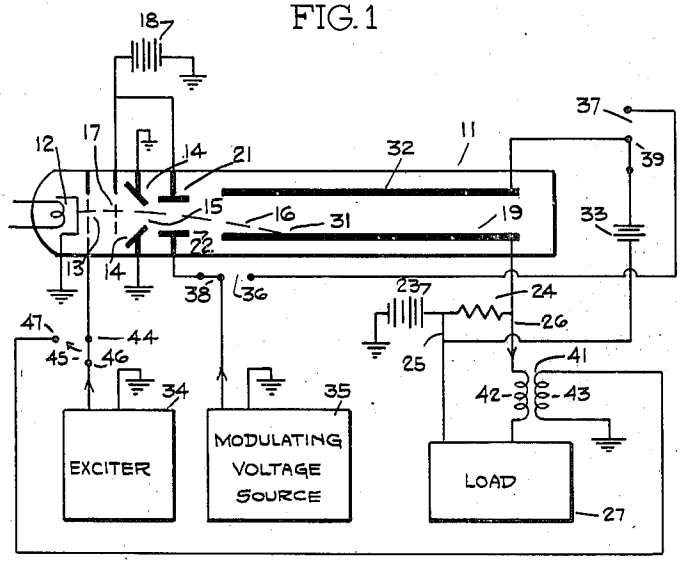


FIG. 2

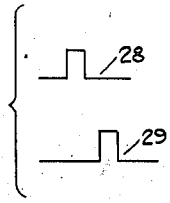
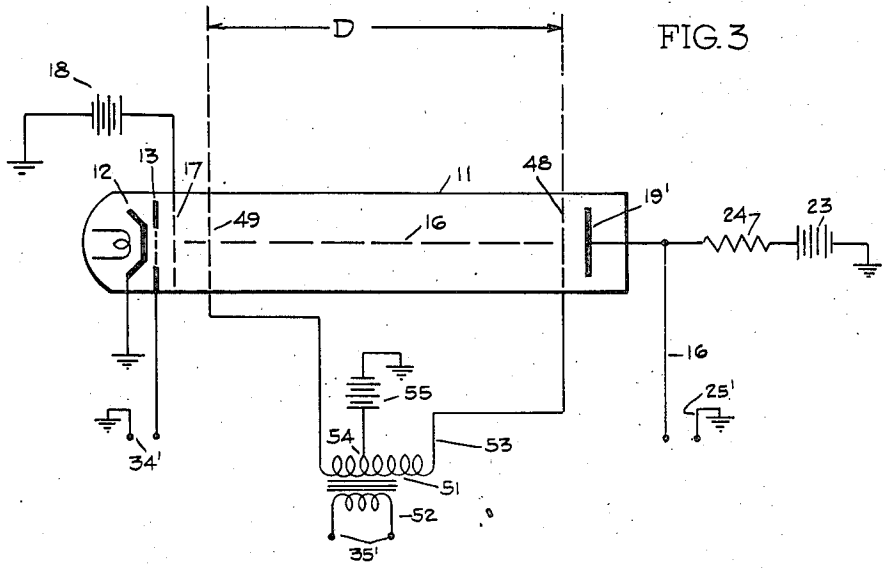


FIG. 3



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VARIABLE TIME DELAY ELECTRONIC APPARATUS

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3 Claims. (Cl. 179—171.5)

1

The present invention relates to space discharge apparatus, and concerns particularly apparatus of the type in which an electric emission beam or electronic beam is produced.

An object of the invention is to provide improved methods and apparatus for producing time delay effects.

Another object is to provide improved methods and apparatus for controlling delay of high frequency signals without employing filter networks.

Another object is to provide arrangements for producing the same absolute delay for all frequency components of a signal.

Another object is to provide a generator of ultra high frequency, frequency modulated or phase modulated signals.

Still another object is to provide a compact, readily operated modulator for producing frequency modulation or phase modulation by means of a relatively weak modulating signal.

A further object is to provide an ultra high frequency oscillator which may be modulated.

Still another object is to provide arrangements for utilization or for control of transit time effects.

Other and further objects and advantages will become apparent as the description proceeds.

In carrying out the invention in one of the preferred embodiments thereof, a discharge tube is provided of the type having means for forming a beam of electrons which may be in the form of a sheet lying along a plane, a cone or other configuration of such a nature that electrons may be deflected so as to bend the beam or sheet of electrons into a distorted shape. A suitable collector plate is provided which has considerable length in the direction of emission of the electrons in the beam so that by deflection of the beam or distortion of the shape thereof, the point at which the electrons impinge upon the collector plate may be varied. Accordingly, time delay effects may be produced as a result of electron transit time. A signal impressed on the electron beam may be variably delayed by means of a second signal or modulating signal arranged to bend or distort the beam or sheet of electrons.

A better understanding of the invention will be afforded by the following detailed description considered in conjunction with the accompanying drawing in which

Fig. 1 is a schematic diagram showing circuit connections of one embodiment of the invention.

Fig. 2 is a graph representing the time delay which may be produced in a signal supplied to the apparatus of Fig. 1, and

2

Fig. 3 is a schematic and circuit diagram of an embodiment of the invention in which an electron beam is varied in velocity instead of being bent or distorted.

Like reference characters are utilized throughout the drawing to designate like parts.

The apparatus illustrated in Fig. 1 comprises a vacuum tube 11, having a conventional indirectly heated cathode 12, a conventional intensity control electrode or grid 13, means for forming the electrons emitted from the cathode 12 into a beam or sheet and an anode or collector.

The beam forming means may take the form as illustrated in Fig. 1 of a pair of beam forming electrodes or plates 14 shown as grounded, having a slit or aperture 15 between them through which a stream of electrons 16 may be emitted and focused if a flat sheet form of beam as desired. It will be understood, however, that if a funnel-shaped beam is desired or a disc-shaped beam consisting of a plurality of radially extending rays, the form and relative positions of the electrodes 12, 13 and 14 may be varied accordingly.

Preferably, a screen grid, lens element, or focusing anode 17 is also provided having means such as a source of direct current 18 for maintaining the focusing anode 17 at a potential above the cathode 12, which for convenience is shown as grounded. The electrode 17 insures also that electrons which have passed through it travel with a velocity substantially independent of the potential on electrode 13.

If a flat sheet form of beam such as illustrated as 16 is employed, the collector or anode may take the form of a longitudinally extending plate 19. It will be understood, however, that the collector 19 will be provided with a suitable form in relation to the other electrodes enumerated according to the shape of beam desired.

For distorting the beam 16, or in the case of a pencil-shaped beam or a ribbon-form beam, simply bending it from a normal central position in the tube 11, suitable deflecting plates such as a pair of electrostatic plates 21 and 22 of the type employed in cathode ray indicators and oscilloscopes are provided. The deflection plates 21 and 22 will, of course, take a suitable form according to the shape of the beam 16 and the corresponding shape of the other electrodes already enumerated. Magnetic deflection instead of electrostatic may also be employed, or if simplified construction is desired, deflecting

voltage may be applied between the electrodes 14, omitting the plates 21—22.

A source of anode voltage 23 is provided for energizing the collector anode 19, and in order to enable a signal to be taken from the apparatus, a load impedance 24 may be connected in series between the collector 19 and the anode voltage supply 23. A pair of conductors 25 and 26 may be connected to the ends of the impedance 24 for connection to a load 27 or other signal receiving means.

If a signal such as a rectangular voltage pulse, for example such as illustrated by the wave 28 of Fig. 2 is applied to the intensity control grid 13, a similar signal having substantially the same shape but delayed as represented by the wave 29 will appear at the output terminal conductors 25 and 26 as the result of the transit time effect, that is to say the time required for the electrons to travel from the emitting cathode 12 to a point 31 at which the beam 16 impinges on the collector 19. The point at which the beam 16 impinges upon the collector 19 may be varied by varying the voltage applied to the beam deflecting means, in this case the deflection plates 21 and 22. By varying the voltage applied to the beam deflecting means, the time delay between the signals 29 and 28 of Fig. 2 may be varied.

Improved operation, particularly with respect to reducing the defocusing effect of the collector 19 upon the electron sheet or beam 16, may be obtained by providing a second long plate-form anode 32 in a complementary position with respect to the collector-anode 19. In the particular form of tube illustrated, the anodes 19 and 32 are both flat plane anodes substantially parallel lying on opposite sides of the center axis of the tube 11 along which the beam 16 would normally travel if undeflected by the deflecting means 21—22. The anode 32 may be held at the same average potential as the anode 19 so that preferably a source of potential difference such as a battery 33 is provided for maintaining the potential of the anode 32 below that of the power-supply for the collector-anode 19.

If desired, a reversable arrangment may be provided in which signals of reversable polarity may be applied to the beam deflecting means 21—22, in which case the beam 16 may be deflected toward either of the anodes 19 and 32 according to the polarity of the beam deflecting voltage or signal. If the anode 32 is connected to the conductor 26 instead of to the conductor 25, signal output of a given polarity may be obtained for beam deflecting signal input of either polarity.

If desired, the anode 32 may be composed of a material forming a good emitter of secondary electrons. In this case, an increased output may be taken from the anode 19, the normal collector-anode. The latter arrangement will be found to be somewhat regenerative. However, regenerative action or oscillation may also be produced by direct coupling as will be explained hereinafter.

If a simplified form of construction is desired, the beam deflecting plates 21 and 22 may be omitted and the deflecting signal may be applied to the anode 32 instead.

It will be understood that deflection of the beam 16 may also be obtained without either the anode 32 or the deflecting plates 21 and 22 by applying a deflecting voltage between the beam forming electrodes 14.

Where the construction of the anodes is such as to produce either a flat sheet 16 of electrons

or a pencil-beam, either of which may be represented by Fig. 1, the anodes 19 and 32 may be relatively flat and action takes place by actual bending of the beam 16. However, if the conformation of the beam forming electrodes and the other necessary electrodes is such as to produce a conical sheet of electrons 16 or a very flat cone such as a sheet of radially extending rays of electrons, the time delay action is produced by beam deflecting means such as the plates 21 and 22 acting to distort the shape of the sheet of electrons, that is changing the angle of the cone or disc of electron emission so as to vary the distance between the cathode 12 and the point 31 at which the electrons impinge upon the collector-anode 19.

The arrangement may be utilized for modulation of a radio frequency signal especially an ultra high frequency radio signal where very rapid variations in polarity and in modulation are required.

For example if the voltage wave form of an exciter 34 is to be modulated by a source of modulating voltage 35, the exciter 34 may be coupled to the intensity control grid 13 of the tube 11, and the modulating voltage source 35 may be coupled to the beam deflecting means, in this case the deflection plates 21 and 22. The load 27 may take the form of antenna or a power amplifier or the like for utilizing the frequency or phase modulated signal. It will be understood that if the carrier from the exciter 34 is to be phase modulated, the modulating source 35 may be directly coupled to the deflecting circuit; on the other hand if the carrier is to be frequency modulated instead a suitable integrating circuit is interposed between the modulating voltage source 35 and the deflecting circuit represented by the deflecting plates 21 and 22.

If a simplified form of tube is desired, the modulating voltage source may be coupled to one of the beam forming plates 14, and the plates 21 and 22 may be omitted or the modulating voltage source 35 may be coupled to the second anode 32, the plates 21 and 22 being omitted. To illustrate the latter connection, double throw switches 36 and 37 are shown having switch blades 38 and 39 respectively shown in positions for closing the circuits producing the arrangement previously described where the plates 21 and 22 are utilized for modulating. If the modulation is to be accomplished or the time delay effect is to be produced by means of the anode 32, the switch blades 38 and 39 are thrown to positions opposite from those shown, whereby the modulating voltage source 35 is disconnected from the plates 21—22 and connected to the anode 32, which is under this circumstance disconnected from the tie-in with the collector anode 19.

The arrangement may be utilized as a simple amplifier for ultra high frequency service or as an ultra high frequency oscillator. For producing an ultra high frequency generator or oscillator, the load circuit may be coupled to one of the control circuits, for example the intensity control grid 13 or the deflection plates 21—22. For the sake of illustration a feed-back link coupling or tickler coil 41 may be provided having a primary winding 42 in series with the load 27 or if desired in series with the load impedance 24 and having a secondary winding 43 adapted to be connected in series with a control circuit.

A double throw switch 44 is shown to illustrate conversion of the apparatus illustrated in Fig. 1

from a carrier modulator in which the wave of the exciter 34 is modulated by the source 35 to a self oscillatory high frequency generator. The switch 44 is illustrated as comprising a movable blade 45 coupled to the intensity control grid 13, a stationary terminal 46 coupled to the exciter 34 and a second stationary terminal 47 to the winding 43 of the feed-back device 41. Other means for feed-back coupling may, of course, be employed. If the blade 45 is moved from the position contacting the terminal 46 to the position contacting the terminal 47, the output of the collector anode 19 will be fed back to the intensity control grid 13 to produce oscillation.

If amplitude modulation is desired instead of phase or frequency modulation, the modulating voltage source 35 may be coupled to the intensity control grid 13 in place of the exciter 34 and the feed-back device 41 may be coupled to the beam deflecting means 21—26 in place of the modulating voltage source 35.

The order of magnitude of phase modulation which can be achieved by the system illustrated in Fig. 1 with the various change over switches left in the positions illustrated in the drawing may be appreciated from a concrete example of various specific dimensions and electrical values. It will be understood, however, that the invention is not limited to specific values or relationships between them, and that the following values are given merely for the sake of illustration. If the length of the anodes 19 and 32 is chosen as five inches, and if 500 volts are applied to the screen grid 17, then at an output frequency or a carrier frequency of 25 megacycles, 360 degrees of phase modulation may be obtained, while at a carrier frequency of 2500 megacycles 36,000 degrees of phase modulation may be obtained.

Even greater phase modulation or deviation may be obtained, if desired, by means of an alternative embodiment in which the velocity of the electron stream is controlled instead of the point of impingement of the stream and anode as illustrated in the arrangement of Fig. 3.

Referring to Fig. 1, it is apparent that by virtue of the input applied to the intensity control grid 13 and by virtue of the fact that electrons leaving the deflecting means 21—22 are traveling at constant velocity substantially independent of the amplitude of the input signal at the intensity control grid 13, the point 31 at which the beam 16 strikes the anode 19 is determined primarily by the intensity of the signal applied by the modulating voltage source 35. Since the target 19 is in the form of a long plate, the distance along the plate 19 which the beam 16 travels before striking can be varied considerably by the variation of the potential of the modulating voltage source 35. In this manner the transit time between a wave supplied by the exciter 34 and an output wave taken from the terminals 25 and 26 is varied.

A similar result may be achieved by employing a fixed point of pick-up or collection of the electrons in the beam 16, and providing means for varying the velocity of the electron stream. In this case the deflection-producing means 21—26 may be omitted and the anode collector or target 19 is changed in shape and position so as to lie across the path of the beam 16. The apparatus illustrated in Fig. 3 may have electrodes 12, 13 and 17 similar to and corresponding to the electrodes shown in Fig. 1. However, the beam forming plates 14 and the beam deflecting

means 21—22 are omitted as well as the complementary anode 32. The collector anode is changed in form and position as represented at 19' in Fig. 3 so as to lie substantially normal to the direction of the beam or ribbon of electrons 16. As in the case of the apparatus of Fig. 1, the conformation of electrodes may also be such as to utilize a sheet of electrons of funnel shape, or to utilize a radially extending electron sheet requiring a concentric arrangement of electrodes where a greater power output is desired than may be available from a pencil beam or a ribbon of electrons.

For varying the velocity of the stream of electrons 16 in the region between electrodes 17 and 19', a velocity changing electrode 48 may be provided, and in order to prevent changes in current at the anode 19' resulting from changes in modulating voltage applied to the electrode 48, a counteracting electrode 49 may be provided which is mounted relatively close to the screen grid or lens element 17. Preferably the velocity controlling electrode 48 is mounted relatively close to the anode 19' in order to exert a maximum effect on the transit time of electrons. The counteracting electrode 49 is preferably supplied with a potential of suitable magnitude 180 degrees out of phase with the potential applied to the velocity controlling electrode 48. The delaying signal or modulating signal from the source 35 may be applied in push-pull, preferably unbalanced between the electrodes 48 and 49. For example, a coupling transformer 51 may be provided having a primary winding 52 with terminals 35' for connection to the delaying or modulating voltage source 35 and having a secondary winding 53 connected between the electrodes 48 and 49 with a tap 54 thereon, preferably connected to a source of negative voltage such as a "C" battery 55 to provide sufficient bias for preventing the electrodes 48 and 49 from drawing current. The other connections may be similar to those employed in the apparatus of Fig. 1. For example, intensity control grid terminals 34' may be provided for connection to a carrier or exciter source 34 and the output may be taken from across the load impedance 24 by means of conductors connected to the ends of the resistor 24, or if desired one of the output conductors may be directly grounded as represented by the conductor 25' in Fig. 3.

The electrodes 48 and 49 may be in grid form or may be constructed as meshes of radially extending strips or rods similar to the velocity control grids provided for the catcher and buncher cavities of ultra high frequency tubes of the Klystrom type, for example.

The amount of delay of the input signal from the terminals 34' or the phase modulation which may be obtained for a given input voltage at the terminals 35' depends upon the length of the drift distance D between the velocity control electrodes 48 and 49.

Certain embodiments of the invention and certain methods of operation embraced therein have been shown and particularly described for the purpose of explaining the principle of operation of the invention, and showing its application, but it will be obvious to those skilled in the art that many modifications and variations are possible, and it is intended therefore to cover all such modifications and variations as fall within the scope of the invention, which is defined in the appended claims.

I claim:

1. In combination, means for producing an electron beam, a collector arranged to receive the electrons of said beam, a velocity controlling electrode disposed athwart the path of said beam, means for applying a modulating potential to said electrode, a second electrode disposed athwart the path of said beam in spaced relation to said first electrode, and means for supplying said second electrode with a potential opposite in phase to the potential of said first electrode.

2. In combination, means for producing an electron beam, a collector arranged to receive the electrons of said beam, a velocity controlling electrode disposed athwart the path of said beam close to said collector, means for applying a modulating potential to said electrode, a second electrode disposed athwart the path of said beam relatively remote from said collector, and means for supplying said second electrode with a potential opposite in phase to the potential of said first electrode.

3. In combination, means for producing an electron beam, means for varying the intensity of said beam at a carrier frequency, a collector

arranged to receive the electrons of said beam, a velocity controlling electrode disposed athwart the path of said beam, means for applying a modulating potential to said electrode, a second electrode disposed athwart the path of said beam in spaced relation to said first electrode, and means for supplying said second electrode with a potential opposite in phase to the potential of said first electrode.

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