

March 17, 1970

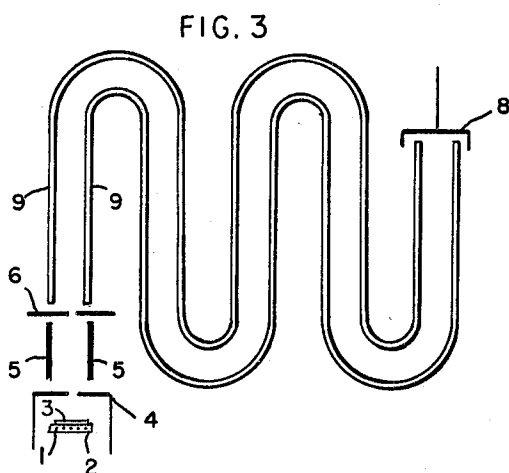
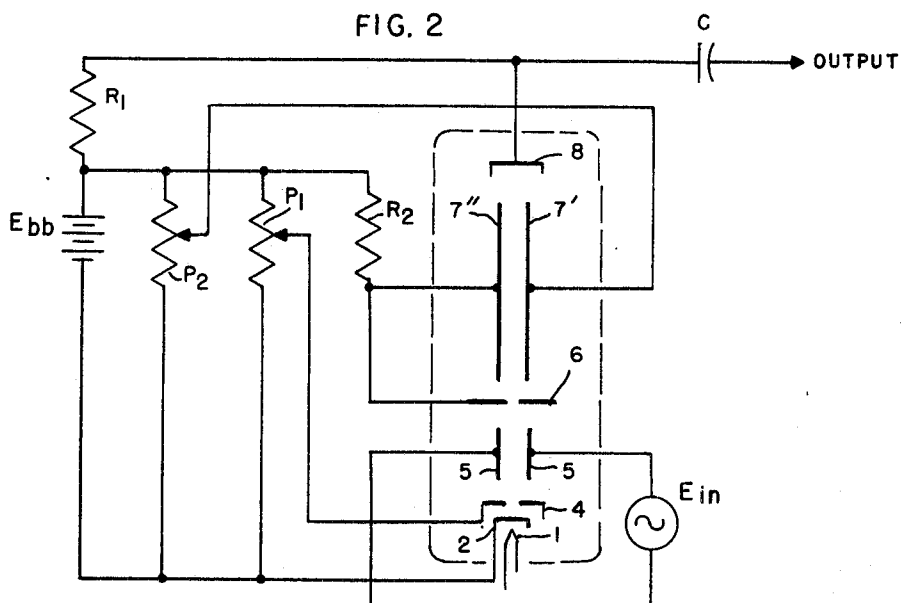
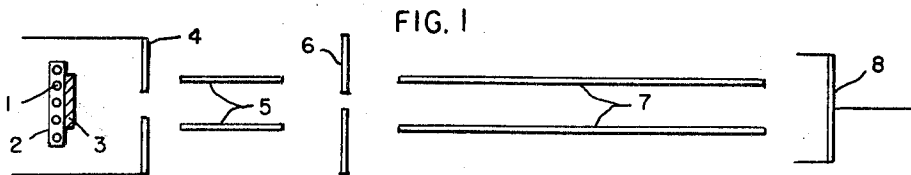
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3,501,702

ZERO CROSSING ELECTRON TUBE AND CIRCUIT

Filed Oct. 12, 1961

2 Sheets-Sheet 1



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FIG. 4

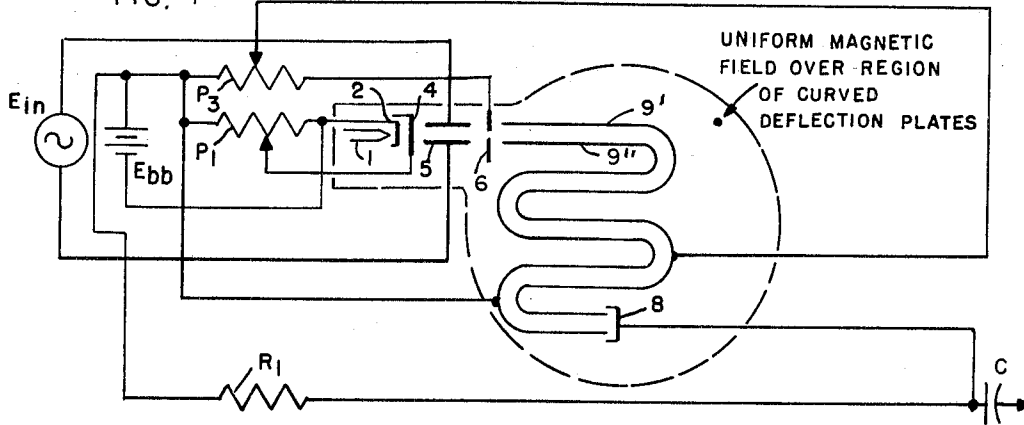


FIG. 5

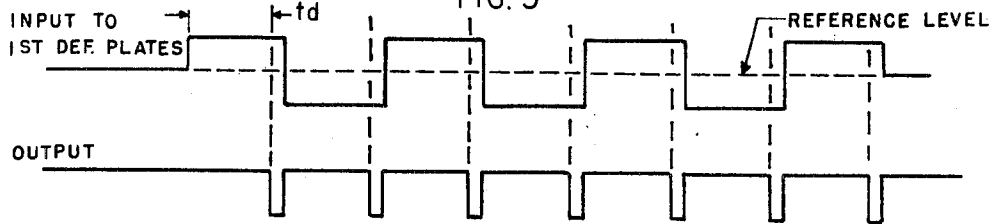


FIG. 6

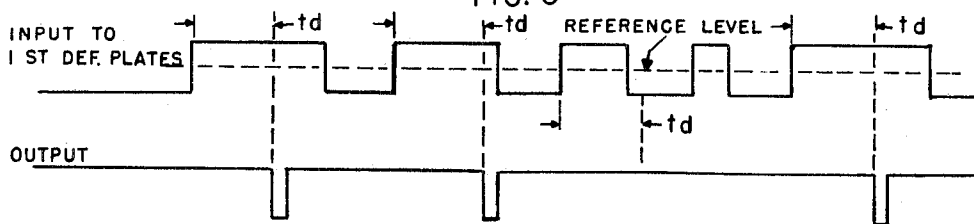
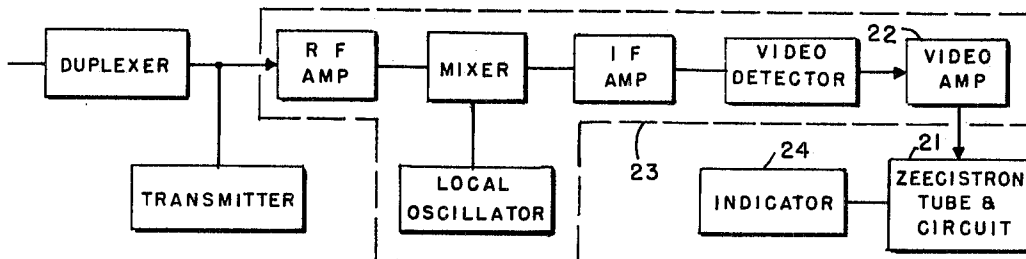


FIG. 7



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ZERO CROSSING ELECTRON TUBE AND CIRCUIT
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U.S. Cl. 328—136

13 Claims

The invention described herein may be manufactured and used by or for the Government for governmental purposes without the payment to me of any royalty therein.

This invention relates to a method and apparatus for separating signals from noise, for statistical wave analysis, and the like. More specifically, the invention relates to a novel cathode-ray tube system in which recurring signals are detected by plural sets of deflecting plates spaced axially along the path of the electron beam of the tube.

The invention consists of an electron tube and circuit which operate to determine whether a "zero" crossing of a wave consisting of signal mixed with noise is followed by a second "zero" crossing at a time not less than a predetermined interval λ . The tube itself with its associated circuit can, therefore, be used to provide an output signal whenever a true signal is present at the input. Since a single tube circuit is used to accomplish this job compared to the complex circuits now required, this means of distinguishing between signal and noise can be added to almost any pulse signal transmission system, either of the radar or communication type, at low cost and with little circuit design effort.

The "zero" crossing tube, for which the name Zeecistron is coined, utilizes the inherent versatility of an electron beam to accomplish a task which would otherwise require a multiplicity of tubes and circuits. In the preferred embodiment an accelerating electrode is used to produce an electron beam which is acted upon by the input signal (a mixture of true signal and noise) on a pair of first deflection plates. The result of this action is to sweep the electron beam through an excursion on an apertured electrode with the beam crossing the aperture every time a "zero" crossing of the signal-noise mixture has occurred. Electrons falling on the aperture pass through it into the second region of the tube at every "zero" crossing whether it is a positive going crossing or a negative going crossing and whether the crossing was due to noise or a signal. The electrons which pass the aperture now enter a second deflection plate system which consists of two plates, spaced equally over their length, but folded or curved to obtain a specifically developed length. This deflection system is located in a uniform magnetic field which is perpendicular to the electric field developed by the voltage across the two plates and is also perpendicular to the direction of motion of the electrons entering the deflection plate system. The voltage across the plates is derived by D.C. coupling to a resistor in series with the apertured electrode so that when current is flowing to the apertured electrode the voltage is sufficient to produce a force on electrons in the deflection plate system which nearly balances the force produced by the magnetic field. Thus electrons which have passed through the aperture will continue to flow, at the velocity of entry into the deflection plate system, along an equipotential line between the two deflection plates as long as the electron beam in the first region remains on the apertured electrode. If a second "zero" crossing, however, occurs before the electrons due to the first crossing have passed through the second deflection plate system, the voltage across the second deflection plates is reduced toward zero as the current to the apertured electrode drops. This unbalances the forces acting on the first electrons and causes them to be collected by one of the deflection plates. No signal appears at the output electrode in

this case. Since the time of transit through the deflection plate system can be adjusted by adjusting the velocity of the electrons entering the second deflection plate system the tube has performed the function of generating an output signal as a result of a "zero" crossing which has not been followed by a second crossing in less than a predetermined time interval. Additional details and other methods of operation and uses for the Zeecistron tube are contained in the detailed description given below.

It is therefore a primary object of the invention to provide a method and apparatus for separating recurring signals from noise.

It is a further object of this invention to provide a method and apparatus for producing an output signal when input signals have a specific relationship in time.

It is an additional object of this invention to provide an electron beam device for achieving the above and other objects.

It is another object of the invention to provide a circuit utilizing the electron beam device for detecting signals in the presence of noise, and the like.

Other objects and features of the invention will be apparent in the following detailed description taken in connection with these drawings in which corresponding elements are represented by the same reference characters throughout:

FIG. 1 represents the basic zero-crossing tube structure;

FIG. 2 is an embodiment of the zero-crossing tube of FIG. 1 in a typical circuit;

FIG. 3 represents an embodiment of the zero-crossing tube structure using curved deflection plates;

FIG. 4 is a circuit using the zero-crossing tube of FIG. 3;

FIGS. 5 and 6 show characteristic waveforms of signals which may be impressed on the first deflection plate of the zero-crossing detector tube and waveforms of the respective output signals derived from the output electrode of the tube; and

FIG. 7 shows the invention in conjunction with a radar system.

The electron beam is an extremely versatile device. It can be used to perform functions which would require a multiplicity of devices and circuits to accomplish the same task. An example of this is the Zero-Crossing System of detection which can be accomplished with a complex circuit containing multivibrators, differentiators, rectifiers, adders, phase-inverters and sawtooth generators. All of these devices can be replaced by an electron tube of special design operating in an appropriate circuit.

First, the Zero Crossing System will be examined to determine its characteristics. The Zero Crossing System of detection is based on the principle that the average time interval between successive zeros of random noise is small compared to the duration of a pulse to be detected. A successful zero crossing detector should, therefore, generate a pulse each time a zero-crossing (or crossing of any predetermined potential level) occurs and reject all signals which are followed by another signal in less than a predetermined time. An electron beam device capable of performing these functions will now be described.

The device shown in FIG. 1 is a type of cathode-ray tube having heater 1, a cathode coating 3 on cathode 2, an accelerating electrode 4, a first pair of deflection plates 5 followed by an apertured electrode 6, a second pair of deflection plates 7, and an output electrode or anode 8. It is to be noted that deflection plates 7 are considerably longer than plates 5. For zero crossing system operation, the tube is incorporated in a circuit as shown in FIG. 2. The input voltage E_{in} consisting of a mixture of noise and the signals to be detected, is applied to the first pair of deflection plates 5. This voltage typically will be in the video output of a radar system.

When a voltage exists between these deflection plates the electron beam is intercepted by apertured electrode 6. As the voltage changes from positive to negative, for example (or crosses a set potential level established by a bias between the two deflection plates), the beam is swept across the aperture in electrode 6, permitting electrons to penetrate the space beyond the apertured electrode. Thus electrons pass the aperture every time a "zero" crossing occurs. The first set of deflection plates and the apertured electrode, described so far, act as a built-in amplifier to provide an amplified signal to the second set of plates when a zero crossing occurs.

The potentials on the second set of deflection plates 7 are adjusted so that there is no voltage between them whenever the beam is intercepted by the apertured electrode. This is accomplished by adjusting the voltage on plate 7' by means of potentiometer P_2 to be equal to that due to the plate supply voltage E_{bb} less the drop across resistor R_2 due to the flow of intercepted beam current, which has been applied to opposite plate 7'' by direct coupling to apertured electrode 6. Electrons which have passed the apertured electrode during a "zero" crossing will see no deflection potential as long as the electron beam passing through the first set of deflection plates continues to fall on the apertured electrode.

A second crossing of the aperture, however, will reduce the beam current to electrode 6, resulting in the appearance of a potential between the second pair of deflection plates, since the decrease in collected beam current will reduce the drop across resistor R_2 , raising the potential of deflection plate 7'' directly coupled to the apertured electrode as compared to the opposite plate 7' whose potential is fixed by potentiometer P_2 . If this second crossing of the aperture has occurred before the electrons flowing between the second pair of deflection plates 7 due to the first cross-over have passed beyond a point where the application of the deflection voltage will cause the electrons to be deflected sufficiently to strike the deflection plate, no current will flow in the output circuit. If, however, the beam has remained on the apertured electrode for a sufficiently long period of time without a "zero" crossover, the electrons due to the first crossover will travel between the second deflection plates without deflection and will be collected at the output electrode. This causes an output pulse through output coupling capacitor C or equivalent A.C. coupling device. The basic design shown in FIG. 2 will give a pulse output whenever a zero crossing has not occurred during a time period.

$$t_c = \frac{L_2}{5.93 \times 10^7 \sqrt{E_{ap}}} \quad (1)$$

where L_2 is the length of the second deflection plates and E_{ap} is the voltage of the aperture electrode, which determines the velocity of the electrons passing through the aperture.

If a crossover occurs before time t_c has elapsed the electrons will be captured by one of the plates. The capture of the electrons by the deflection plates will also depend on the separation of the deflection plates.

Equation 1 indicates that in order to operate in a time region which will be of interest, the length of the second deflection plates will have to be long and the accelerating potential of the apertured electrode will have to be low. The overall length of the second deflection plates, which affects the physical size of the tube, may be kept within reasonable bounds by using another embodiment of the invention as shown in FIG. 3 when operated in a circuit such as that shown in FIG. 4.

The device shown in FIG. 3 is constructed in a manner similar to that of FIG. 1 up to the apertured electrode.

The second deflection plates 9 now consists of a curved pair of plates 9' and 9'' with a constant separation over the length of the plates. Electrons which pass through apertured electrode 6 and enter the curved deflection plate system with a velocity v_0 will flow through the deflection plate system and be collected by the output electrode 8 provided that the curved deflection system is in a magnetic field B which tends to balance out the voltage across the deflection plates, V_d , in accordance with the relationship: $B = V_d / av_0$ where a is the separation between the deflection plates.

Referring now to FIG. 4, the curved version of the "zero" crossing detector will operate in the following manner. Electrons are accelerated by accelerating electrode 4 through first deflection plates 5 where the input signal E_{in} deflects the beam. At the time of a "zero" crossing, electrons pass through the aperture of the apertured electrode 6. At all times other than a zero crossing the electrons strike electrode 6 and no electrons pass through the aperture of this electrode. The setting of potentiometer P_3 has been adjusted to derive a voltage V_d across the deflection plates 9' and 9'' which produces a force on the electrons sufficient to nearly, but not completely, cancel the force produced by the constant magnetic field B which is perpendicular to the direction of the initial velocity of the electrons as well as the deflection voltage. As long as the apertured electrode is collecting full current to maintain V_d by the voltage drop across P_3 , this approximate balance will be maintained and the electrons will follow an equipotential line until they arrive at the output electrode. If, however, a second "zero" crossing occurs before the electrons have passed through or almost through the deflection system, the voltage across the deflection plates will drop from V_d towards zero. This removes the electric field which has maintained the near-balance with the magnetic field, and the electrons within the deflection plate system will be deflected towards the deflection plate which was previously the negative plate of the two deflection plates, traveling in a circular path with a radius $R = Mv_0 / eB$. If the separation between the electrodes a has been selected such that a is less than $4R$ (or, conversely, for a fixed separation between the plates, v_0 has been adjusted so that $R = a/4$), the electrons will be collected by the deflection plate before a half circle has been completed. The curved version of the zero crossing detector tube will, therefore, provide an output signal only when a second "zero" crossing has not occurred.

Other methods of extending the time delay in the second system (FIG. 4) may also be used. One such possibility is the use of a magnetic field value which will yield cycloidal or trochoidal motion within the deflection plate system until the motion is disturbed by a second "zero" crossing of the aperture.

The relationship between the input signal to the first set of deflection plates is shown for several illustrative cases in FIGS. 5 and 6. As can be seen, a signal appears at the output after a "zero" crossing has occurred at the input provided that a second crossing has not occurred before the electrons, which have entered the second deflection plate system as a result of the first crossover, are collected by the anode. The time interval td is a function of the developed linear length of path between the curved, second deflection plate system and is inversely proportional to the velocity of the electrons, or the square root of the aperture electrode voltage. This time interval can, therefore, be adjusted over a considerable range, to achieve time delay levels as large as 5 microseconds or greater. The output pulse is delayed with respect to the leading edge of an input pulse (first crossover) by a duration equal to the time of flight of electrons in the second set of deflection

plates. Thus the device can be used as an electronic variable delay line by inserting a pulse whose duration is equal to or greater than the maximum achievable time delay and by varying the aperture voltage and the second deflection plate voltage. Increasing these two voltages while maintaining the relationship (assuming the curved form of second deflection plates) $Vd=E_{ap}$ where Vd =the voltage across the deflection plates in the absence of a zero crossing and E_{ap} =the aperture voltage, will result in a decreasing time delay. This type of operation is illustrated in FIG. 5, with the time delay set for a maximum.

FIG. 6 illustrates the rejection and acceptance characteristics of the device; it does not necessarily correspond to a useful type of operation. As can be seen in the figure, input pulses greater than a set value of time delay result in an output pulse delayed with respect to the start of the pulse. No pulse output appears because of the end of the pulse since the spacing between pulses is less than the critical value of delay td .

The tube and circuits of FIGS. 2 and 4 may be used in a radar system by coupling the zero-crossing tube to the video output of the receiver, as shown in FIG. 7, in which the zero-crossing detector system 21 is inserted between video amplifier 22 of radar receiver 23 and indicator 24. The video information is applied to the first set of deflection plates as the input signal to the tube 21. An output pulse is obtained only when the time between a pair of "zero" crossings is greater than the transit time of electrons within the second deflection plate system. Since there is a statistically significant difference in the time between a crossing due to noise and the time between crossings due to a pulse of known width, the probability of detecting the presence of a known pulse can be made to be high by proper choice of the critical time delay within the second set of deflection plates, with a small probability of having an output pulse due to noise alone. The zero-crossing tube, therefore, serves to separate the noise from the pulse and to provide a pulse output with a fixed delay (for which compensation can be made in the radar range circuit) and with a fixed pulse width and height. With proper design of the tube and choice of circuit constants, the output amplitude can be sufficient to be fed directly to a cathode-ray tube for visual presentation. (Essentially the zero-crossing tube can be designed to provide voltage amplification as well as perform the function of eliminating the noise signals.) If it is desired to process the data further, such as for MTI purposes, etc., and it is desired to reconstitute the original pulse signal, the output of the zero-crossing tube can be used to trigger a monostable multivibrator or the equivalent to generate a pulse whose duration is equal to the original duration of the transmitted pulse.

The concept of the tube and cooperating circuitry was generated primarily as a means of detecting pulses hidden by natural or man-made noise. The method by which this is accomplished is described above and in the discussion of use in a radar system. The tube and circuit could be used in a secrecy system for either radar or pulse-code communication where the original pulse signals are mixed with video noise and the combined resultant is used to modulate a CW amplifier. In addition, since the tube is basically a correlation device, it could be used in other types of cross-correlation circuits.

The device can be used as well in the important field of statistical analysis of waveforms in radar and communication. Present methods employ a multiplicity of electronic devices whereas the device disclosed herein carries on all operations in one tube. The result is that measurements may be made more simply and quickly and probably with greater accuracy.

The foregoing disclosure relates to a preferred embodiment of the invention. Numerous modifications or

alterations may be made therein without departing from the spirit and scope of the invention set forth in the appended claims.

What is claimed is:

1. A system for generating an output signal as a result of a zero-potential crossing of an input signal, which crossing is not followed by a second such crossing in less than a predetermined time interval, comprising: means for forming an electron beam, first deflecting means for sweeping said electron beam according to said input signal, a blocking means having an aperture therein for passing said electron beam only on a zero crossing of said input signal, a potential source, impedance means, second deflecting means connected to said blocking means and through said impedance means to said potential source to adjust the potential of said second deflection means to permit passage of said electron beam when said beam is intercepted by said apertured electrode and to attract said beam to said second deflecting means when a second zero crossing occurs before said predetermined time interval, and a collecting means to receive said beam when passed by said second deflecting means.

2. The system of claim 1 wherein said first and second deflecting means each include a pair of parallel coplanar plates.

3. The system of claim 2 wherein said second deflecting means is considerably longer than said first deflecting means and wherein each plate of said pair of plates of each deflecting means is symmetrical about the axis of the portion of said beam passing therethrough.

4. The system of claim 1 wherein said first deflecting means includes a pair of parallel coplanar plates and said second deflecting means includes a pair of parallel curved plates and which further comprises a means for supplying a uniform magnetic field over the region of said second deflecting means.

5. The system of claim 4 wherein said second deflecting means has considerably greater length along the path of said beam than said first deflecting means, and wherein said uniform magnetic field is perpendicular to the electric field resulting from said potential of said second deflecting means and is also perpendicular to the direction of motion of the beam entering said second deflecting means.

6. A system for detecting pulses having an interval greater than a predetermined time, comprising: an electron gun having a heater, a cathode, and an accelerating electrode; a deflection means; means to apply an input signal to said deflection means; a deflection system having a first and a second deflection plate; an apertured electrode; a first resistor having one end connected to said first deflection plate and to said apertured electrode; a voltage source connected between said cathode and the other end of said first resistor; first and second potentiometers each shunting said voltage source and having slider arms connected to said second deflection plate and to said accelerating electrode, respectively; a collector electrode; a second resistor connecting said voltage source to said collector electrode; and a capacitor having one end connected to said collector electrode and the other end acting as the output of said system.

7. The system of claim 6 wherein said deflection means includes a pair of parallel planar elements and wherein said first and second deflection plates are parallel elements.

8. The system of claim 7 wherein said first and second deflection plates are planar elements considerably longer than the planar elements of said deflection means.

9. The system of claim 7 wherein said first and second deflection plates are curved elements having a length considerably longer than the length of said planar elements of said deflection means.

10. An electron beam device and circuit therefor for detecting signals in the presence of noise, comprising a tube having a longitudinal axis, an electron gun positioned

substantially on said axis and including a cathode and an accelerating electrode, a first pair of deflection plates spaced about said axis and beyond said gun, an apertured electrode beyond said first pair of deflection plates having an aperture on said axis, a second pair of deflection plates spaced about said axis and beyond said apertured electrode, and an anode on said axis beyond said second pair of plates; signal input means connected to said first pair of deflection plates; a first resistor having one end connected to said apertured electrode and to one plate of said second pair of deflection plates; a supply voltage source connected between said cathode and the other end of said resistor; first and second potentiometers each shunting said supply voltage source and having slider arms connected to the other plate of said second pair of deflection plates and to said accelerating electrode, respectively; a second resistor connected between said supply voltage source and said anode; and an output coupling means comprising a capacitor having an end connected to said anode.

11. Apparatus for separating recurring signals from noise comprising: an electron gun having a cathode and an accelerating electrode; a pair of deflection plates; an input signal source connected to said pair of deflection plates; an apertured electrode; a deflection system having a first and a second deflection plate; means for supplying a uniform magnetic field over the region of said deflection system; a supply voltage source connected to said cathode and to said second plate; a first potentiometer shunting said supply voltage source and having a slider arm connected to said accelerating electrode; a second potentiometer having end terminals connected to said supply voltage source and to said apertured electrode, respectively, and having a slider arm connected to said first plate; a collector electrode; a resistor connected between said collector electrode and said supply voltage source; and an output coupling means connected to said collector electrode.

12. The apparatus of claim 11 wherein said first and second plates are parallel curved elements considerably longer than said pair of deflection plates, said second plate is normally at a more positive potential than said first plate, and the magnetic field from said magnetic field supplying means is perpendicular to the electric field resulting from the potential difference developed across said

first and second plates and is also perpendicular to the direction of motion of electrons passing between said first and second plates.

13. Apparatus for separating recurring signals from noise comprising: an electron beam tube having an anode, a pair of continuous metallic plates equally spaced over their entire length and folded over in such a manner that said plates form a raceway in which the direction of travel changes by 180° at least two times, an apertured electrode, a pair of deflection plates, an accelerating electrode, a cathode, a heater, and means to apply a uniform magnetic field over the region of said metallic plates; means for applying said signal that is to be separated from noise to said deflection plates; a D.V. voltage source having two terminals; means to couple said anode to one terminal of said voltage source; means to couple one of said metallic plates to said one terminal of said voltage source; a first potentiometer having a slider arm; means to connect said potentiometer between said apertured electrode and said one terminal of said voltage source; means to connect said slider arm of said first potentiometer to the other of said metallic plates; a second potentiometer having a slider arm; means to connect said second potentiometer across said voltage source; means to connect said slider arm of said second potentiometer to said accelerating electrode; means to connect said cathode to the other of said terminals of said voltage source; and a capacitor coupled to said anode.

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