

Dec. 26, 1950

J. R. PIERCE
HIGH-SPEED OSCILLOSCOPE

2,535,317

Filed Jan. 26, 1949

FIG. 1

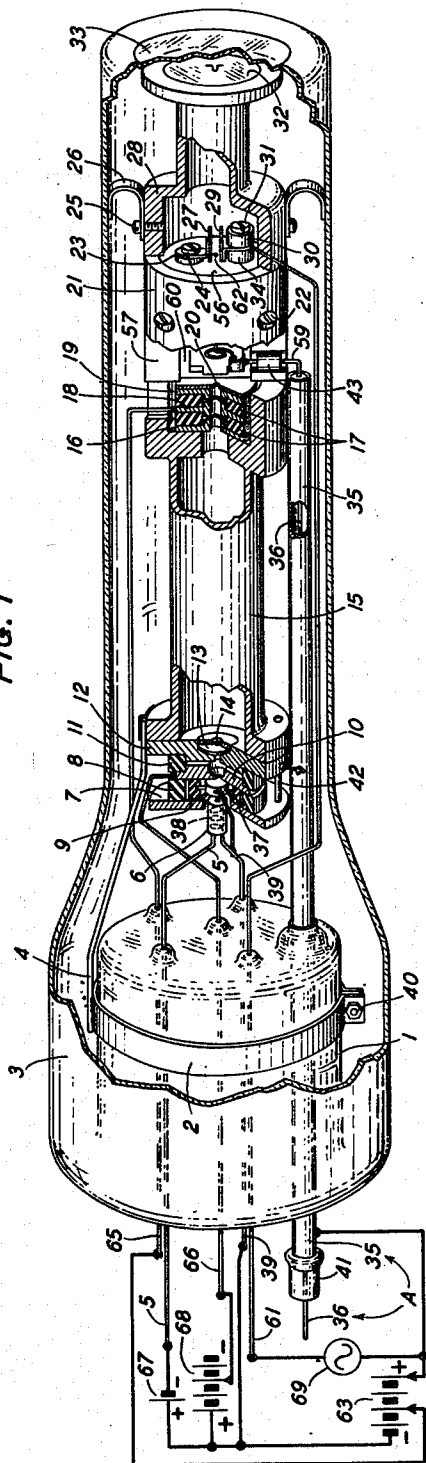


FIG. 3

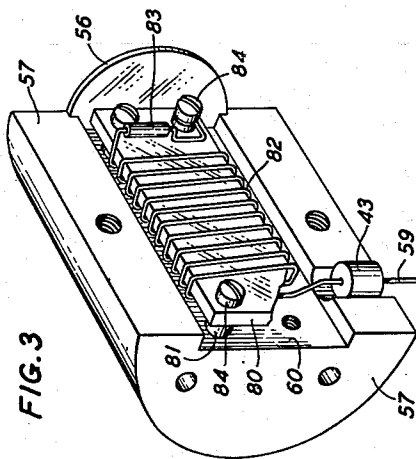
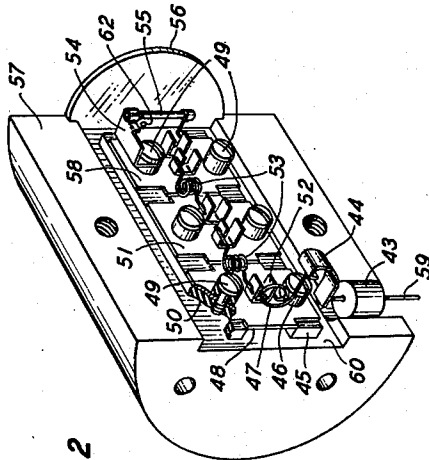


FIG. 2



INVENTOR
J. R. PIERCE
BY
N. S. Ewing
ATTORNEY

UNITED STATES PATENT OFFICE

2,535,317

HIGH-SPEED OSCILLOSCOPE

John R. Pierce, Millburn, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application January 26, 1949, Serial No. 72,799

11 Claims. (Cl. 250-156)

1 This invention relates to oscilloscopes particularly such as may be used for observing very high frequency periodic signals.

The general objective of the invention is to provide a device for viewing periodic signals and which will respond to frequencies from 0 to 500 megacycles or higher.

Another objective is to provide such a device having good voltage sensitivity so as to be adapted to use without an amplifier.

Another objective is to provide such a device presenting a matched resistive load at the vertical deflecting plate leads.

The usefulness of high speed oscilloscopes for some purposes has been seriously limited due to lack of sensitivity and band-width limitations. Oscilloscopes operable at very high frequencies have required high level signals for their operation and the observation of low level signals has been practically prohibited due to the difficulty of providing signal amplification while meeting the frequency and band-width requirements.

The performance of the oscilloscope of this invention whereby limitations of former such instruments are overcome is achieved largely through two means; the use of optical magnification of the trace on the screen and the use of a traveling wave deflection system in order to provide good vertical deflection sensitivity without band-width limitation because of transit time.

The invention is explained more fully in the following description and the accompanying drawings, in which:

Fig. 1 is a drawing, partly schematic, showing a complete oscilloscope tube and the power supply circuits.

Fig. 2 shows to an enlarged scale certain details of Fig. 1, some of which details are not visible in the Fig. 1 showing.

Fig. 3 shows an alternative to Fig. 2 which may be substituted in the Fig. 1 device in place of the parts shown in Fig. 2.

Referring now to the drawings in more detail, Fig. 1 shows a view of the oscilloscope tube from what would normally be the top so that vertical deflections would be deflections toward and away from the observer of the drawing. The evacuated envelope of the tube which may be of glass is designated 3. This envelope is provided with an optically ground window 33 through which the fluorescent screen 32 may be observed. The thermionic cathode 37 is coated with electron emissive material on the surface facing the screen 32. The cathode is connected to lead 39 which

2 extends through a seal in the envelope. The cathode 37 is heated by means of a coil heater 38 in combination with a heat shield 6. The heater leads are attached to leads 39 and 5 which pass through seals in the envelope and connect to battery 67 from which energy for the heater is obtained. The cathode 37 is supported by ceramic 9 and a metallic member 7 in juxtaposition to a focusing modulator electrode 10. Electrode 10 is spaced from member 7 by ceramic 8 and is spaced by means of ceramic 11 from an accelerating electrode 12 which is held positive with respect to the cathode by means of battery 63 to which it is connected through lead 35. The cathode 37, electrode 10 and electrode 12 cooperate to produce and focus a beam of electrons sharply on a small aperture 14 centrally located in a metallic disc 13. The intensity of this beam may be controlled by means of a modulating voltage supplied by battery 68 between cathode 37 and electrode 10, electrode 10 being connected to lead 66. The beam emerges from aperture 14 as a narrow cone of electron flow and passes through the supporting member 15 to fall upon the electron lens formed by electrodes 16, 18 and 19 which are supported and insulated from each other by ceramics 17. It will be noted that the assembly of tube elements including member 15 is supported at one end by member 4 fastened to ring 2 which is clamped by screw 40 around the reentrant portion 1 of the envelope and is held in position at the other end by members 26 fastened by screws 25 to member 28. Electrodes 16 and 19 of the electron lens are at the same potential as the accelerating electrode 12 and electrode 18 is held at some lower potential by means of the tap on battery 63 which is connected to lead 65. The potential of electrode 18 is so adjusted as to focus the electron beam into a small spot, an image of aperture 14, on the fluorescent screen 32. The fluorescent material of screen 32 may be deposited on the side facing the lens and the cathode of a thin sheet of glass or other transparent material. The fluorescent screen 32 is supported by member 28 which is attached to members 57 and 21. An aperture 20 defines and limits the diameter of the electron beam before it passes into the region of deflection. The electron beam may be deflected in a horizontal direction by a voltage source 69 which is applied through lead 61 to a horizontal deflecting plate 29. Plate 29 is supported from the metallic disc 56 by means of ceramic washers 30 and 34 and screw 31. The disc 56 having an aperture 62 for passage of the

3

electron beam is held in contact with members 57 and 21. The other horizontal deflecting plate 27 is at the potential of the accelerating electrode 12 it being fastened by angle member 23 and screw 24 to disc 56 which is connected through members 57 and 15, electrode 12 and lead 15 to battery 63 as well as to source 69. Vertical deflection is accomplished by the structure of Fig. 1 shown in detail in Fig. 2. This structure consists of member 57 and a number of elements mounted thereon most of which are obscured in Fig. 1 by member 21 which is fastened to member 57 by screws 22 and with member 57 surrounds and shields the deflecting and other elements mounted on the surface 60 of member 57. In Fig. 2, 48, 51 and 58 are three deflecting plates. These are interconnected by inductances 53 in such a manner as to form a wave filter. 55 is a combination resistance and inductance which terminates the filter formed by plates 48, 51 and 58 and inductances 53 in its characteristic impedance over a wide range of frequencies. The resistance combination 55 is connected at one end to member 57 by the supporting connector 54 and the associated screw 49. The smooth face 60 of member 57 forms the other plate or side of the vertical deflecting system. The deflecting plates 48, 51 and 58 are supported and insulated from member 57 by the ceramic strips and washers 45, 50 and 46 and screws 49. The input end of the filter is connected through an inductance 47, a strip conductor 44 and a lead 59 supported by a ceramic ring 43 to the inner conductor 36 of a coaxial transmission line formed by conductor 36 and outer conductor 35 and shown in Fig. 1. This transmission line is designed to have the same characteristic impedance as the wave filter structure. The coaxial transmission line is sealed through the envelope 3 in a vacuum-tight manner as indicated in Fig. 1 and a vacuum-tight seal 41 is made external to the envelope between the inner conductor 36 and outer conductor 35, so that the external connections or vertical deflection terminals are at the ends of conductors 35 and 36 at A in Fig. 1 and the pulse or other voltage to be observed may be applied at this point. The trace on the fluorescent screen 32 may be viewed through the window 33 by means of a microscope.

Fig. 3 shows a deflecting structure which may be used in place of the structure shown in Fig. 2. It will be seen that the Fig. 3 showing is interchangeable with the showing of Fig. 2 and may be substituted for it in Fig. 1. In the Fig. 3 structure the vertical deflecting elements are the plane face 60 of member 57 and an opposing face of a coil 82 which is wound on a ceramic or other insulating core 80 and is proportioned to have the same characteristic impedance as the terminating resistance 83 and the coaxial line formed of center conductor 36 and outer conductor 35 of Fig. 1. The core 80 is supported parallel to face 60 by means of spacers 81 and screws 84. One end of resistance 83 is connected to member 57 through one of the supporting screws 84.

As transmission lines for the electric wave connected to the terminals 35 and 36 at A in Fig. 1 to produce vertical deflections of the electron beam both the filter structure of Fig. 2 and the coil 82 of Fig. 3 are designed so that the phase velocity of the wave traveling along the filter structure or along the coil is substantially equal to the velocity of the electron beam. This is important in order that the advantages of the deflecting structures be realized. Under this con-

4

dition the electron beam which travels along either of the structures between it and the face 60 of member 57, in the field of the traveling wave, is cumulatively deflected. The oscilloscope is usable over a wide range of frequencies. It is especially adapted to operate at very high frequencies and the transmission line deflecting system is more than one, or several, wavelengths long at the higher frequencies in order to provide high deflection sensitivity. When the device is used at low frequencies it is obvious that the line will be shorter as measured in wavelengths and may be less than one wavelength long.

In a typical case the electron accelerating voltage may be 1000 volts corresponding to an electron velocity about $\frac{1}{10}$ the speed of light. The modulator electrode 10 voltage may be zero with respect to the cathode and the voltage of lens electrode 18 may be about 500 volts with respect to the cathode. The aperture in electrode 10 may be about 0.03 inch in diameter, the aperture 14 may be about 0.001 inch in diameter, the aperture 20 may be about 0.03 inch in diameter and aperture 62 may be about 0.040 inch in diameter. The deflecting plates 48, 51 and 58 may be spaced about 0.04 inch from the plane face 60 of member 57 and each may be about $\frac{1}{3}$ inch long and the deflecting plates 27 and 29 may be about $\frac{1}{4}$ inch square and spaced about 0.4 inch apart. The distance from aperture 14 to electrode 18 may be 3 inches and the distance from electrode 18 to the fluorescent screen 32 may be 3 inches. The impedances of the coaxial line formed by 35 and 36 and of the filter formed by 48, 51, 58 and 53 may be 75 ohms and resistance 55 may be 75 ohms. The phase velocity of the filter may be $\frac{1}{10}$ of the speed of light, corresponding to the electron velocity.

It is to be understood that the above-described embodiments are illustrative of the application of the principles of the invention and the dimensions given are merely typical. Other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. An oscilloscope comprising an evacuated envelope containing a cathode, means for producing a beam of electrons along a path from the cathode, electron beam deflecting means located along said electron path remote from the cathode, said deflecting means comprising a high frequency transmission circuit extending adjacent to said electron path for several wavelengths at the highest frequencies used and having a wave propagation velocity substantially equal to the velocity of the electrons in said beam, whereby the electric field of said circuit is impressed upon said adjacent electron path and said beam is cumulatively deflected therealong when the circuit is energized, means for energizing said circuit at the end nearer the cathode and a viewing screen located in the path of the electron beam beyond said deflecting means.

2. An oscilloscope comprising an evacuated envelope, means for producing a beam of electrons along a path within said envelope, electron beam deflecting means located along said path and comprising a high frequency transmission circuit extending along said path and having a wave propagation velocity approximating the velocity of the electrons in said beam and a viewing screen located in said path beyond said deflecting means.

3. An oscilloscope comprising an evacuated

5

envelope, means for producing a beam of electrons along a path within said envelope, means located along said path and excited by the signal to be viewed for producing a beam deflecting field traveling along a portion of said path at a velocity approximating the velocity of the electrons in said beam and a viewing screen located in said path beyond the region of said deflecting field.

4. In combination, means for producing a beam of electrons along a path within an evacuated envelope, electron beam deflecting means located along said path, said deflecting means comprising a high frequency non-resonant transmission circuit extending along said path and having a wave propagation velocity approximating the velocity of the electrons in said beam and a viewing screen located in said path beyond said deflecting means.

5. In combination, means for producing a beam of electrons along a path in an evacuated envelope, means located along said path and excited by a signal to be viewed for producing an electron beam deflecting field traveling along a portion of said path at a velocity approximating the velocity of the electrons in said beam, and a viewing screen located in said path beyond the region of said deflecting field.

6. An oscilloscope comprising an evacuated envelope containing a cathode, electrodes for producing an electron beam along a path from said cathode to a viewing screen, electron beam deflecting means located along said path and adjacent thereto comprising a high frequency transmission circuit producing when energized a traveling electric field in a portion of said path traveling in the same direction as said electron beam and at substantially the same velocity as said electron beam, said transmission circuit being positioned to deflect the electron beam in a certain plane, and another deflecting means producing when energized an electric field in a portion of said path and positioned to deflect the electron beam in a plane at an angle to said certain plane.

7. An oscilloscope comprising an evacuated envelope within which are two electron beam deflecting systems each arranged to produce an electric field for deflecting an electron beam in one of two planes which are substantially perpendicular to each other, one of said deflecting systems comprising an electric wave transmission circuit extending along the path of said electron beam and arranged to produce one of said electric fields traveling along said circuit at a velocity within the range of practical electron velocities and means within said envelope for projecting said beam of electrons at a velocity substantially the same as the velocity of said traveling field through both said fields to a viewing screen, the electron beam passing through said traveling field in the direction of travel of the field.

8. An oscilloscope comprising an evacuated envelope containing a cathode, a viewing screen, means for projecting a beam of electrons from said cathode along a path to said viewing screen and electron beam deflecting systems for deflecting said beam in two planes angularly displaced from each other, one of said deflecting systems comprising a filter type of high frequency transmission circuit extending along said electron beam path, said circuit comprising a metallic member presenting a surface to one side of the

6

electron beam path, a plurality of metallic members presenting surfaces opposed to said first-mentioned metallic member and arranged along said beam path on the side opposite said first-mentioned metallic member so that the electron beam passes between said surface of said first-mentioned metallic member and the group of said surfaces of said plurality of metallic members, inductances interconnecting the said plurality of metallic members whereby the interconnecting inductances and the capacitances between said first-mentioned metallic member and said plurality of metallic members form said filter type high frequency transmission circuit, means for applying high frequency deflecting voltage to said transmission circuit between one of said plurality of metallic members and said first-mentioned metallic member and a terminating load for said circuit connected between another one of said plurality of metallic members and said first-mentioned metallic member.

9. An oscilloscope comprising an evacuated envelope containing a cathode, a viewing screen, means for projecting a beam of electrons from said cathode along a path to said viewing screen and electron beam deflecting systems for deflecting said beam in two planes angularly displaced from each other, one of said deflecting systems comprising a helical coil type of high frequency transmission circuit extending along said electron beam path, said last-mentioned deflecting system comprising a metallic member presenting a surface to one side of the electron beam path, a helical coil axially parallel to said beam path and positioned therealong presenting a coil surface opposed to said surface of said metallic member and on the opposite side of said beam path from the said surface of said metallic member so that the electron beam passes between said surface of said metallic member and said coil surface, means for applying high frequency deflecting voltage to said transmission circuit between said coil and said metallic member and a terminating load for said circuit connected between said coil and said metallic member.

10. An oscilloscope according to claim 9 having a window in said envelope for observation of said viewing screen.

11. An oscilloscope comprising an evacuated envelope containing a cathode, a viewing screen, means for projecting a beam of electrons from said cathode along a path to said viewing screen, electron beam deflecting systems for deflecting said beam in two planes angularly displaced from each other, one of said deflecting systems comprising a high frequency transmission circuit extending along said path and capable of producing a traveling electric field along a portion of said path and traveling in the same direction as the electron beam and at substantially the same velocity as said beam and means for energizing said circuit with a deflecting voltage.

JOHN R. PIERCE.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,932,084	Opsahl	Oct. 24, 1933
2,263,733	Knoll	Nov. 25, 1941
2,425,682	Liebmann	Aug. 12, 1947
2,463,617	Hartley	Mar. 8, 1949