Jan. 19, 1960

C. H. MOULTON

2,922,074

ELECTRON BEAM DEFLECTION STRUCTURE

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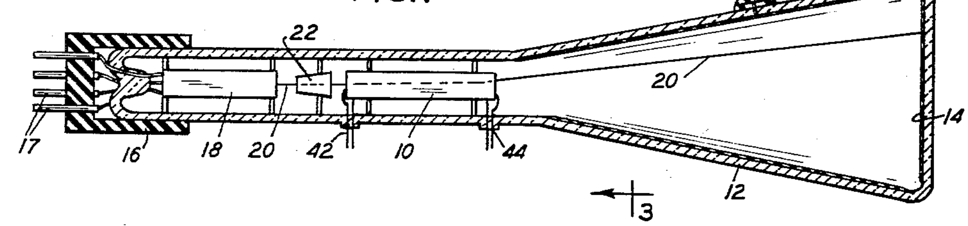
FIG. 1



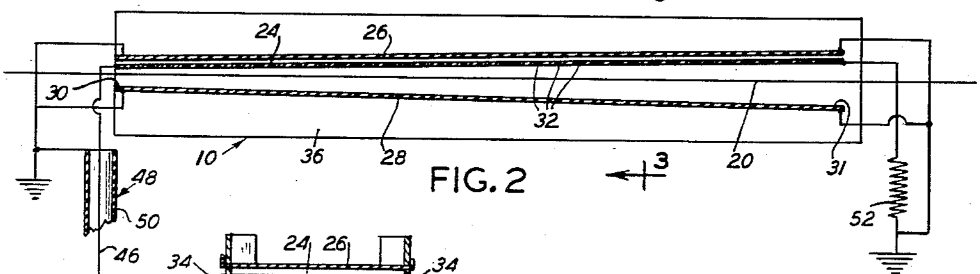


FIG. 2

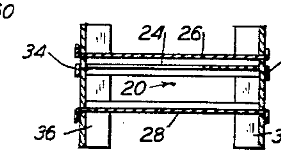


FIG. 3

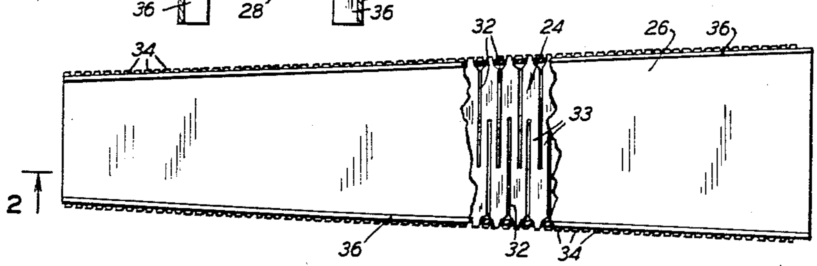


FIG. 4

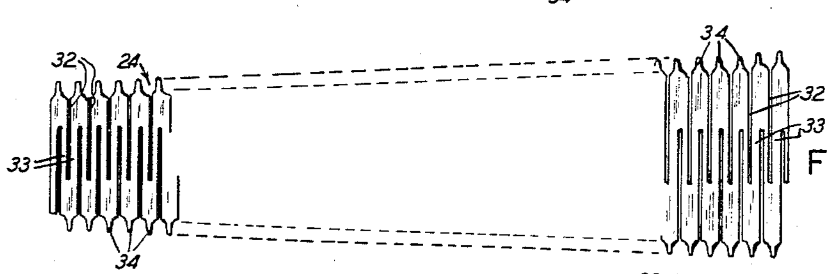


FIG. 5

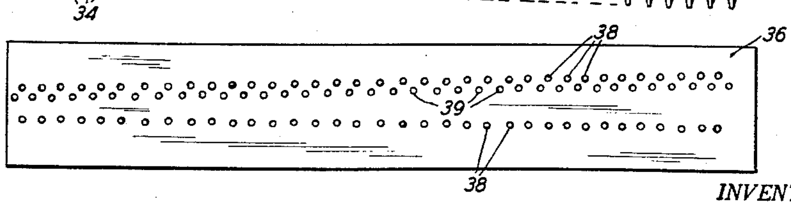


FIG. 6

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ELECTRON BEAM DEFLECTION STRUCTURE

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11 Claims. (Cl. 315—23)

This invention relates to a deflection structure for a cathode ray tube and more particularly to an improved deflection structure in which a signal voltage is caused to travel along a deflection plate forming part of such structure at substantially the same velocity as that of the electrons in the electron beam of the tube so as to extend the frequency range and transient signal response of such tube.

The structure of the present invention is particularly useful in cathode ray tubes for cathode ray oscilloscopes. Both horizontal and vertical deflection in such tubes is usually of the electrostatic type. That is to say, two pairs of deflection plates at right angles to each other are usually employed with the individual plates of each pair positioned on opposite sides of the beam of electrons. In order to secure adequate deflection of the beam, the deflection plates must have substantial length in the direction of the beam. This places an upper limit upon the frequencies of the signal voltage which can be effectively impressed upon the vertical deflection plates. Also, since transient signal voltages involve extremely high frequencies, the length of the plates in the direction of electron travel also limits the accuracy of the response of the cathode ray tube to such transient signal voltages.

It will be apparent that maximum deflection for a signal voltage of given amplitude will occur when the transit time of an electron in the beam along the length of the plates is less than the time corresponding to a half wave length of the signal voltage and that a partial or complete reversal of the deflection voltages on the vertical deflection plates occurs when the transit time of the electron along the plates exceeds the time represented by such half wave. When the transit time becomes equal to the time corresponding to a full wave of the signal voltage, there is substantially equal deflection in opposite directions to produce zero deflection. Such zero deflection also occurs at harmonics of the lowest frequency which produces zero deflection. The magnitude of the deflection is therefore a function of frequency as well as of amplitude of the signal voltage and the effects discussed above become of importance at frequencies for which the transit time of an electron along the deflection plates is a substantial fraction of the period corresponding to a wave length of the signal voltage.

In accordance with the present invention, a deflection structure is provided in which the signal voltage is propagated along a deflection plate in the direction of electron movement at a velocity which is substantially equal to the velocity of the electrons in the beam. Furthermore, the structure provides for suppression of reflections of such signal voltages so that the resulting deflections becomes substantially independent of the frequency of the applied signal voltage and transient response is very materially improved. In a preferred embodiment of the invention, a deflection plate is provided which has a plurality of conducting elements extending transversely of the electron beam. Each of such conducting elements has a surface

forming part of the deflection surface of the deflection plate and the conducting elements have their ends connected together alternately on opposite sides of the deflection plate so as to provide a zigzag path for the signal voltage propagated along the plate. The electrical characteristics of the deflection structure utilizing the plate can be made such that a signal travels the length of the plate at the same speed of the electrons in the electron beam and the signal voltage is effective at all times to produce a deflection force on the electrons in the beam.

The structure of the deflection plate of the present invention lends itself to the provision of a deflection structure which has the same characteristic impedance as an input conductor, such as a coaxial cable. That is to say, the deflection plate of the present invention may be positioned between a pair of conducting plate members so that the deflection plate, in effect, forms a continuation of the central conductor of the coaxial cable and the conducting plate members, referred to, form an effective continuation of the outer conductor of the coaxial cable. In such a structure, the deflection plate of the present invention is positioned closer to one of such conducting plate members than the other and diverges from such other conducting plate member from the entrance end of the structure for electrons toward the outlet end for such electrons to provide a diverging passage between the deflection plate and such other conducting plate member. The inductance per unit length of the deflection structure containing the deflection plate may be varied by varying the length of the transverse conducting elements and their spacing from each other and the capacitance per unit length can be varied by varying the width of the deflection plate and the associated conducting plate members and also the spacing between the deflection plate and one of the conducting plate members. By properly varying the factors mentioned, the deflection plate structure may be caused to have the characteristic impedance of any of the usual flexible commercial coaxial cables employed in test instruments while, at the same time, providing a velocity of signal voltage propagation along the plate which is within the range of velocities which can be imparted to electrons in the electron beam. Also, the outlet end of the deflection structure can be terminated in the characteristic impedance of the coaxial cable and deflection structure so that reflections of the signal voltage back along the deflection plate and the coaxial cable are substantially eliminated.

It is therefore an object of the present invention to provide an improved deflection structure for cathode ray tubes which has improved frequency and transient response.

Another object of the invention is to provide an improved deflection plate for the cathode ray tubes of oscilloscopes in which a signal voltage is applied at one end of the deflection plate and travels along a zigzag path so as to have a net velocity in the direction of propagation of electrons in the electron beam of the tube which is substantially the same as that of the electrons in such beam.

Another object of the invention is to provide a deflection structure for the beam of a cathode ray tube in which a signal is propagated along a deflection plate in the direction of the electrons in the electron beam of such tube at a rate substantially equal to the velocity of the electrons in the beam and in which the deflection structure has substantially the same characteristic impedance as the connector structure for connecting said plate to a signal source and in which the other end of the deflection structure can be terminated in such characteristic impedance.

A further object of the invention is to provide a deflection plate structure for a cathode ray tube in which a deflection plate is positioned between a pair of conducting plate structures so as to provide a characteristic impedance substantially the same as that of a coaxial cable employed for impressing a signal upon one end of the deflection structure and in which a deflection plate causes the signal voltage pressed thereon to travel in a zigzag path with a net velocity of the direction of the electron beam substantially equal to the velocity of the electrons in such beam and in which such structure provides for terminating the other end of the structure at the characteristic impedance of such structure.

Other objects and advantages of the invention will appear in the following description of a preferred embodiment shown in the attached drawings of which:

Fig. 1 is a diagrammatic vertical cross section of a cathode ray tube embodying the deflection structure of the present invention;

Fig. 2 is a vertical cross section through the deflection structure of the present invention and also diagrammatically showing the electrical connections thereto;

Fig. 3 is a vertical cross section taken on the line 3—3 of Fig. 2;

Fig. 4 is a plan of the deflection structure of the present invention with parts broken away;

Fig. 5 is a plan of the deflection plate of the present invention in its condition before installation in the deflection plate structure of Figs. 2 to 4; and

Fig. 6 is a side elevation view of one of the insulating supporting plates for the deflection plate of Fig. 5.

Referring more particularly to the drawings, the deflection plate structure **10** of the present invention is positioned within the glass envelope **12** of a cathode ray tube having a phosphor coating **14** on the interior of the large end of the envelope **12**. The envelope **12** of the tube is provided with a conventional plug **16** having the usual pins **17** for insertion into a socket, the pins **17** furnishing electrical connections to an electron gun **18** which may be a conventional type providing a beam **20** of electrons which first pass between conventional horizontal deflection plates **22** and then through the vertical deflection structure **10** of the present invention and thereafter impinge upon the screen formed by the phosphor coating **14** and the end of the envelope **12** of the tube. The deflection structure **10** includes a deflection plate **24** positioned between a pair of conducting plate members **26** and **28** with the deflection plate **24** nearer the conducting plate member **26** than the conducting plate member **28**. The electron beam indicated by the line **20** in Fig. 2, enters the deflection structure at the entrance end **30** thereof. It passes between the deflection plate **24** and the conducting plate member **28** and leaves the deflection structure **10** through the outlet end **31** of the deflection structure. During its passage through the deflection structure, the beam **20** is deflected vertically in Fig. 2 by a signal voltage propagated along the deflection plate **24** from the inlet end **30** of the deflection structure to the outlet end **31**.

The preferred form of the deflection plate **24** is most clearly shown in Figs. 4 and 5. Such plate is a thin sheet of conducting material, preferably a spring metal which will withstand bending, for example, a sheet of Phosphor bronze. The deflection structure **10**, including both the deflection plate **24** and the plates **26** and **28**, preferably tapers so as to be wider at its outlet end **31** than at its inlet end **30**. The deflection plate **24** has a plurality of narrow slots **32** extending inwardly alternately from opposite edges thereof, the inner ends of the slots overlapping to provide laterially extending conductor elements **33** which extend transversely of the beam of electrons **20** and provide a zigzag path for a signal voltage propagated along the deflection plate from the inlet end **30** of the structure to the outlet end thereof. In the plate shown, the conductor elements are all of the same length but the width of the elements is made progressively smaller and the width of the slots between such elements correspondingly larger from the inlet to the outlet end of the deflection structure. The portions of the deflection plate **24** between the slots at the opposite edges of the deflection plate terminate in small support tabs **34** and such support tabs engage side support elements **36** in the form of thin sheets of insulating material, for example, mica. The support elements **36** are of substantially the same length as the deflection plate **24** and conducting plate members **26** and **28** and have formed therein a plurality of rows of small apertures **38** and **39**. The row of apertures **38** is positioned between two rows of apertures **39** and nearer one of the rows of apertures **39**. The apertures **38** are spaced to correspond to the tabs **34** on the deflection plate **24** and such tabs are inserted into the apertures **38** of supporting plates **36** at each side of the deflection plate **24**. The tabs **34** are then bent over as shown in Fig. 3. The two conducting plate members **26** and **28** are also provided with similar tabs **34** which extend through the apertures **39** in the support element **36** and are bent over as shown in Fig. 3. This structure provides a rigid boxlike structure in which the deflection plate **24** is rigidly supported by the support elements **36** in properly spaced relationship with the conducting plate members **26** and **28** which are also rigidly supported by the support elements **36**. The support elements **36** may be supported within the envelope **12** of the cathode ray tube in any desired manner. The envelope **12** may be provided with a suitable connector structure **42** adjacent the inlet end **30** of the deflection structure **10** providing for external connection to the deflection plate **24** and conducting plate members **26** and **28**. Also, the envelope **12** may be provided with a connector structure **44** adjacent the outlet end **31** of the deflection structure **10**, the connector structures each having a pair of conductors extending through the walls of the envelope **12** and sealed therein in any suitable or conventional manner.

As indicated in Fig. 2, the central conductor **46** of a coaxial cable **48** may be connected to the deflection plate **24** at the inlet end **30** of the deflection structure and the grounded outer cylindrical conductor **50** may be connected to the conducting plate members **26** and **28**. At the outlet end **31** of such deflection structure **10**, the conducting plate members **26** and **28** may be connected together and also preferably to ground. The outlet end of the deflection plate **24** are also connected to the conducting plate members **26** and **28** through a resistor **52** which preferably has a value of resistance equal to the characteristic impedance of the coaxial cable **48**. The resistor **52** may obviously be positioned internally of the envelope **12** but the structure shown in Fig. 1 provides for external connection of the deflection structure to the resistor **52**.

The characteristic impedance of the deflection structure **10** may be made substantially the same as that of the coaxial cable **48** or other transmission line employed for supplying a signal voltage to the inlet end of the deflection structure. That is to say, the characteristic impedance of the deflection structure **10** is a function of its inductance per unit length and its capacitance per unit length. The inductance per unit length may be varied over a substantial range by varying the length and width of the slots **32** and, similarly, the capacitance per unit length may be varied over a considerable range by varying the width of the deflection plate **24** and conducting plate members **26** and **28** and also varying the distance between the deflection plate **24** and the conducting plate member **26**. It is entirely possible to provide a deflection structure with a substantially constant characteristic impedance equal to any of the coaxial cables commercially available and conventionally employed in test instruments. Furthermore, such characteristic impedances may be obtained while providing a net velocity of signal propagation in the direction of the travel of electrons in electron beam **20**, which is substantially the same as the velocity of such electrons. Since the characteristic impedance of the deflection structure **10** is substantially the same as that of the coaxial cable **48** and the outlet end of the deflection structure is terminated in a resistor having a value substantially equal to such characteristic impedance, reflections of signal voltage are substantially eliminated and a signal voltage applied through the coaxial cable **48** to the inlet end of the deflection structure travels along the deflection plate **24** at the same speed as the electrons in the beam **20** and is absorbed by the terminating resistor **52**. Vertical deflection in cathode ray oscilloscope tubes having the vertical deflection structure of the present invention becomes substantially independent of frequency from zero frequency to an upper cutoff frequency which may be several hundred megacycles and the response to transient signal voltages is very materially increased.

While the cathode ray tube illustrated is particularly adapted for connection to the output of a single-ended amplifier or other signal source having one side grounded, it is entirely possible to employ two properly spaced and diverging deflection plates **26** connected to the output of a push pull amplifier or other double-ended source of signal voltage so that signal voltages in phase opposition travel along such deflection plates at the same speed as the electrons in the beam being deflected. Such a deflection structure may also have the same characteristic impedance as a balanced line connected to the input end of the deflection structure and the outlet end of such structure may be similarly terminated in its characteristic impedance. Also, it is obvious that the relative positions of the vertical deflection structure and the horizontal deflection plates may be reversed so that the electron beam first passes through the vertical deflection structure and that either, or both, the vertical and horizontal deflection may be produced by deflection structures having a zigzag path for a signal voltage propagated along a deflection plate.

While I have disclosed the preferred embodiment of my invention, it is understood that the details thereof may be varied and that the scope of the invention is to be determined by the following claims.

I claim:

1. A deflection plate for causing deflection of a beam of electrons traveling in a predetermined direction along one surface of said plate when a signal voltage is applied to said plate, said plate comprising a plurality of electrical conducting elements extending transversely of said direction and spaced from each other in said direction to provide a series of parallel elements with adjacent ends and narrow slots between said elements, each of said elements having a surface in alignment with a similar surface on the next adjacent elements to provide said one surface, each of the intermediate elements of said series having one end electrically conductively connected to the adjacent end of the next preceding element in said series and its other end electrically conductively connected to the adjacent end of the next succeeding element in said series to provide a zigzag electrically conductive path along said one surface for signal voltages propagated along said plate in said direction.

2. A deflection plate for causing deflection of a beam of electrons traveling in a predetermined direction along one surface of said plate when a signal voltage is applied to said plate, said plate being a sheet of electrical conducting material having a plurality of slots spaced from each other in said direction and each extending inwardly from one edge of said plate and terminating short of the opposite edge of said plate to provide a plurality of series connected electrically conducting elements, said elements extending transversely of said direction and being spaced from each other in said direction by said slots, alternate ones of said slots extending inwardly from opposite edges of said plate to provide a zigzag electrically continuous conductive path through said elements for signal voltages propagated along said plate in said direction.

3. A deflection plate for causing deflection of a beam of electrons traveling in a predetermined direction along one surface of said plate when a signal voltage is applied to said plate, said plate being a thin plate of metal having a plurality of slots spaced from each other in said direction and each extending inwardly from one edge of said plate and terminating short of the opposite edge of said plate to provide a plurality of series connected electrically conducting elements extending transversely of said direction and spaced from each other in said direction by said slots, alternate ones of said slots extending inwardly from opposite edges of said plate to provide a zigzag electrically continuous conductive path through said elements for signal voltages propagated along said plate in said direction.

4. A deflection plate for causing deflection of a beam of electrons traveling in a predetermined direction along one surface of said plate when a signal voltage is applied to said plate, said plate being a thin sheet of metal having a greater length than width and tapering in width from a relatively narrow width at one end to a relatively wider width at the other end, said plate having a plurality of slots spaced from each other in said direction and each extending inwardly from one edge of said plate and terminating short of the opposite edge of said plate to provide a plurality of elongated conducting elements extending transversely of said direction and spaced from each other in said direction by said slots, alternate ones of said slots extending inwardly from opposite edges of said plate to provide a zigzag conductive path through said elements for signal voltages propagated along said plate in said direction.

5. A deflection plate for causing deflection of a beam of electrons traveling in a predetermined direction along one surface of said plate when a signal voltage is applied to said plate, said plate being a thin sheet of metal having a greater length than width and tapering in width from a relatively narrow width at one end to a relatively wider width at the other end, said plate having a plurality of slots spaced from each other in said direction and each extending inwardly from one side edge of said plate and terminating short of the opposite edge of said plate to provide a plurality of elongated conducting elements extending transversely of said direction and spaced from each other in said direction by said slots, alternate ones of said slots extending inwardly from opposite edges of said plate to provide a zigzag conductive path through said elements for signal voltages propagated along said plate in said direction, said elements all being of substantially the same length and progressively decreasing in width from said one end to said other end, said slots correspondingly progressively increasing in width from said one end to said other end.

6. A deflection plate for causing deflection of a beam of electrons traveling in a predetermined direction along one surface of said plate when a signal voltage is applied to said plate, said plate being a sheet of electrical conducting material having a plurality of slots spaced from each other in said direction and each extending inwardly from one edge of said plate and terminating short of the opposite edge of said plate to provide a plurality of electrical conducting elements extending transversely of said direction and spaced from each other in said direction by said slots, alternate ones of said slots extending inwardly from opposite edges of said plate to provide electrically conductive connections between said elements alternately at opposite sides of said plate and a zigzag electrically conductive path through said elements for signal voltages propagated along said plate in said direction, the connections between said elements terminating in supporting tabs extending outwardly from the edges of said deflection plate for attachment to a supporting structure.

7. A deflection plate for causing deflection of a beam of electrons traveling in a predetermined direction along one surface of said plate when a signal voltage is applied to said plate, said plate being of thin sheet metal having

a plurality of slots spaced from each other in said direction and each extending inwardly from one edge of said plate and terminating short of the opposite edge of said plate to provide a plurality of electrical conducting elements extending transversely of said direction and spaced from each other in said direction by said slots, alternate ones of said slots extending inwardly from opposite edges of said plate to provide electrically conductive connections between said elements alternately at opposite sides of said plate and a electrically conductive zigzag path through said elements for signal voltages propagated along said plate in said direction, the connections between said elements at said ends of said elements terminating in bendable supporting tabs extending outwardly from the edges of said deflection plate for attachment to a supporting structure.

8. A deflection structure for a cathode ray tube having means therein for producing a beam of electrons, said structure comprising a pair of conducting plate members spaced from each other for receiving said beam between said plates, said plate members diverging from each other in the direction of electron travel in said beam and providing inlet and outlet ends for said beam, a third plate member positioned between said conducting plate members and nearer one of said conducting plate members than the other so as to be positioned on one side of said beam, said third plate member being constructed of a plurality of conducting elements extending transversely of said beam and having adjacent ends and being spaced from each other in said direction by narrow slots to provide a series of parallel elements, each of the intermediate elements of said series having one end conductively connected to the adjacent end of the next preceding element in said series and its other end conductively connected to the adjacent end of the next succeeding element in said series to provide a zigzag conductive path through said elements for signal voltages propagated along said third plate member, and supporting means for said plate members.

9. A deflection structure for a cathode ray tube having means therein for producing a beam of electrons, said structure comprising a pair of conducting plate members spaced from each other for receiving said beam between said plates, said plate members diverging from each other in the direction of electron travel in said beam and providing inlet and outlet ends for said beam, a third plate member positioned between said conducting plate members and nearer one of said conducting plate members than the other so as to be positioned on one side of said beam, said third plate member being constructed of a plurality of conducting elements extending transversely of said beam and having adjacent ends and being spaced from each other in said direction by narrow slots to provide a series of parallel elements, each of the intermediate elements of said series having one end conductively connected to the adjacent end of the next preceding element in said series and its other end conductively connected to the adjacent end of the next succeeding element in said series to provide a zigzag conductive path through said elements for signal voltages propagated along said third plate member, and supporting means for said plate members comprising insulating members secured to and extending between the lateral edges of said plate members, said plate members being wider adjacent said outlet end than adjacent said inlet end.

10. A deflection structure for a cathode ray tube having means therein for producing a beam of electrons, said structure comprising a pair of conducting plate members spaced from each other for receiving said beam between said plates, said plate members diverging from each other in the direction of electron travel in said beam and providing inlet and outlet ends for said beam, a third plate member positioned betweeen said conducting plate members and nearer one of said conducting plate members than the other so as to be positioned on one side of said beam, said third plate member being constructed of a plurality of conducting elements extending transversely of said beam having adjacent ends and spaced from each other in said direction by narrow slots to provide a series of parallel elements, each of the intermediate elements of said series having one end conductively connected to the adjacent end of the next preceding element in said series and its other end conductively connected to the adjacent end of the next succeeding element in said series to provide a zigzag conductive path through said element for signal voltages propagated along said third plate member, supporting means for said plate members, conducting means extending to the exterior of said tube from said inlet end to provide for impressing a signal voltage between said third plate member and said conducting plate members and conducting means extending to the exterior of said tube from said outlet end.

11. A deflection system for a cathode ray tube having means therein for producing a beam of electrons, said system including a deflection structure comprising a pair of conducting plate members spaced from each other for receiving said beam between said plates, said plate members diverging from each other in the direction of electron travel in said beam and providing inlet and outlet ends for said beam, a third plate member positioned between said conducting plate members and nearer one of said conducting plate members than the other so as to be positioned on one side of said beam, said third plate member being constructed of a plurality of conducting elements extending transversely of said beam and having adjacent ends and being spaced from each other in said direction by narrow slots to provide a series of parallel elements, each of the intermediate elements of said series having one end conductively connected to the adjacent end of the next preceding element in said series and its other end conductively connected to the adjacent end of the next succeeding element in said series to provide a zigzag conductive path through said elements for signal voltages propagated along said third plate member, supporting means for said plate members, said deflection structure including conducting means extending to the exterior of said tube adjacent said inlet end of said structure to provide for impressing a signal voltage between said third plate member and said conducting plate members, a connector structure for connecting said conducting means to a source of signal voltage, said deflection structure having substantially the same characteristic impedance as said connector structure, and means for terminating said outlet end of said deflection structure with a value of resistance substantially equal to said characteristic impedance.

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CERTIFICATE OF CORRECTION

Patent No. 2,922,074 January 19, 1960

Clifford H. Moulton

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 5, line 21, for "plates 26" read -- plates 24 --.

Signed and sealed this 5th day of July 1960.

(SEAL)
Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents