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S. GOLDBERG ET AL
ELECTRON STREAM DEFLECTION SYSTEM OF FOLDED
TRANSMISSION LINE TYPE
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3,280,361

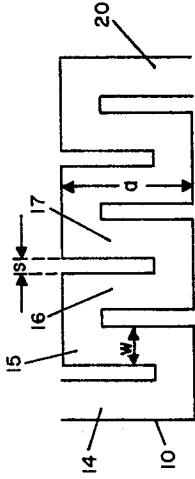


FIG. 2

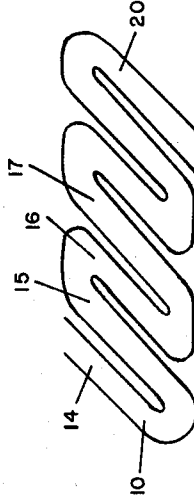


FIG. 4

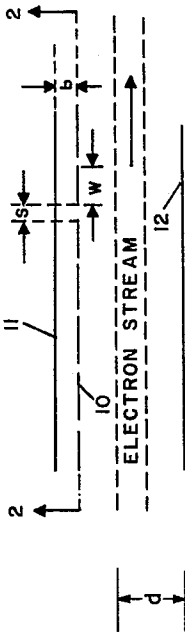


FIG. 1

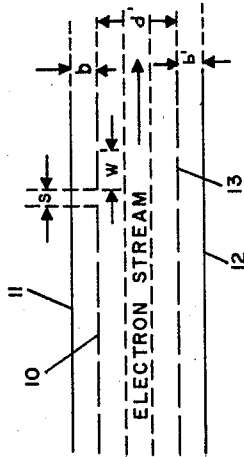


FIG. 3

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ELECTRON STREAM DEFLECTION SYSTEM OF FOLDED TRANSMISSION LINE TYPE

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This invention relates to electron stream deflection systems and more particularly to cathode-ray deflection systems of the traveling-wave transmission-line type.

A large number of electron stream deflection systems are known in the prior art. Parallel plates are typical of those deflectors which may be characterized by a lumped capacitance. Such deflectors have proven useful with deflecting signals having frequencies up to approximately 10 megacycles. For frequencies up to 100 megacycles, periodic lumped series inductance between series lumped capacitance, such as found in helical deflectors, has provided good response. At still higher frequencies, a distributed parameter transmission line with additional periodic loaded distributed series inductances can be utilized over a very narrow band of high frequencies and also at very low frequencies. At intermediate frequencies, however, the phase velocity and the characteristic impedance of such a transmission line has a very dispersive effect upon the electron stream, and thus it is not suited for use as a wide-band deflection system in a cathode-ray tube.

None of these systems, and, in fact, no deflection system known to the applicants, is capable of good frequency response from D.C. to beyond 10 gigacycles.

It is, therefore, an object of this invention to provide a transmission-line cathode-ray deflection system capable of good frequency response over a frequency range from D.C. to beyond 10 gc.

Other and further objects will be explained hereinafter and will be more particularly pointed out in the appended claims. In summary, the present invention comprises a planar conductive element folded into a serpentine configuration so that successively predetermined portions are disposed adjacent to but spaced from one another along the direction of the electron stream so that the electron stream passes each portion in sequence, a first planar electrode disposed parallel to and at a first predetermined distance from said folded element and on the side thereof remote from the electron stream, and a second planar electrode disposed parallel to and at a second predetermined distance from said folded element on the opposite side of the electron stream from the folded conductor. Preferred constructional details are hereinafter explained.

The invention will now be described in connection with the accompanying drawings,

FIGURE 1 of which is a side view of a preferred embodiment of the invention;

FIGURE 2 is a view of FIGURE 1 taken along the line 2—2 thereof looking in the direction of the arrows;

FIGURE 3 is a side view of a modification of the invention shown in FIGURE 1; and

FIGURE 4 is a view of a modification of the element shown in FIGURE 2.

Referring first to FIGURE 2, an electrically conductive strip 10 of, for example, Kovar, is formed into a serpentine or zig-zag shape having a series of successively disposed portions 14, 15, 16 . . . 20, of substantially equal length lying in the same plane. Deflection signals may be applied to the end of portion 14 and follow along strip 10 through each of the successive portions 15, 16 . . . 20. Strip 10 and plate 11 (see FIGURE 1) form

a transmission line. The configuration of strip 10 provides a uniform traveling-wave transmission line, so that regardless of deflection signal frequency, the electron stream sees the same deflection signal as the stream passes through the deflection region, thereby effecting linear deflection of the electron stream without introducing distortion. Helical deflection systems tend to present the same traveling-wave properties but such systems provide a less uniform transmission line which has a more dispersive effect upon the electron stream. Parallel plates do not have these properties and this is one reason why they lack the frequency response of helical and folded strip deflection systems.

Another important advantage of this configuration resides in the fact that there is coupling in only one plane. As can be seen, the only coupling between adjacent portions is the coupling in the plane of the strip itself between strip portions on either side of each portion and the end sections connecting the portions. This is, indeed, very different from the coupling found in adjacent portions of a helical deflection system where coupling exists in many planes with the resultant effect that the electron stream is influenced by such coupling and this influence causes a dispersive effect upon the electron stream.

In FIGURE 1, the strip 10 is shown disposed between a pair of planar conductive plates 11 and 12. As pointed out above, strip 10 and plate 11 form a transmission line and the distance therebetween, *b*, is much less than the distance between strip 10 and plate 12. The electron stream flows between strip 10 and plate 12. The deflection system of FIGURE 1 is an unbalanced, single-ended system. Plates 11 and 12 are connected to a reference potential, preferably ground. Two major advantages of this configuration are the flexibility in impedance matching and the increased shielding provided by the plates 11 and 12. Helical deflection systems are subject to random waves that cause noise in the deflection area which will introduce distortion into the system. The sandwiching of the strip 10 and the electron stream between plates 11 and 12 produces a shield against most of these random waves thereby providing greater accuracy in the deflecting system.

Of still greater importance, this configuration allows the impedance matching of the transmission line to be almost independent of the electric field intensity acting on the electron stream. Most of the impedance matching is determined by the separation distance *b* between strip 10 and plate 11 while separation distance *d* between strip 10 and plate 12 has only a slight effect upon the impedance of the system. The spacing *d* is determined by the magnitude of linear deflection desired and it determines the intensity of the electric field acting upon the electron stream. The system maintains its extensive frequency response for wide variations in the spacing *d*. Plate 12 need not be disposed parallel to strip 10 or plate 11, although this is the preferred arrangement.

The positioning of plate 11 with respect to strip 10 is very important. As pointed out above, strip 10 is disposed adjacent the electron stream and plate 11 is adjacent strip 10 on the side opposite to the electron stream. Plate 11 is preferably co-extensive with and parallel to strip 10. The distance between strip 10 and plate 11 is shown as *b* in FIGURE 1. This distance is a major factor in determining the characteristic impedance of the deflection system and, therefore, is most important in matching the system's impedance to that of the source of deflection signals. It should, however, be noted that strip 10 and plate 12 could be used without plate 11 and the system would still be operable and maintain its great frequency response. In such a configuration the characteristic impedance is determined primarily by separation

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distance d . The use of plate 12 is preferred, nevertheless, for its impedance matching and shielding effects.

Other important factors in the construction of this deflection system are the spacing between adjacent portions of the strip shown as s in FIGURE 2, the width w of each portion, and the thickness t of the strip 10. Were the spacing s between adjacent portions infinite, then the effect of the phase velocity and the characteristic impedance upon the electron stream would be completely non-dispersive. This, of course, is the ideal and impossible of attainment. We have, however, discovered that the optimum configuration for this deflection system resides in an arrangement whereby the ratio of the distance s between adjacent portions to the separation distance b between the strip 10 and plate 11 is substantially equal to or greater than unity. This ratio takes into consideration a 3 db cut-off frequency. If this ratio were slightly less than unity, say 0.75, the system would still maintain many of its advantages but its response would be less linear.

Other factors which influence the characteristic impedance of the system are the ratio of the thickness t of strip 10 to the width w and the ratio of the width w to the separation distance b . As the value of w/b decreases the characteristic impedance increases. The increase in characteristic impedance is linear where t/w is equal to zero. As the thickness increases, however, the increase in impedance is less than a linear function. We have found, for example, that in the case of a 50-ohm impedance, the ratio of w/b is equal to approximately 5 where the ratio of t/w is less than 0.2.

The length a of each of the portions 14, 15, 16, . . . 20 and the number of such portions to be used are determined by the characteristics of the cathode-ray tube in which the deflection system is to be used. The length a of each of the portions and the number of such portions is governed by the requirement that the total length of strip 10 divided by the electromagnetic phase velocity of the deflecting signals must equal the straight line length of the deflection field divided by the electron axial velocity.

It should be noted that this system provides deflection for the broadest electron-stream cross-sectional shape. This is in contrast to other systems, particularly helical deflecting systems, where the electron stream must have very small cross-sectional areas. The width w of each portion of strip 10 controls the upper limit of the cross-sectional dimension of the electron stream. The applicants' system can handle the broadest electron stream for a given ratio of the microwave phase velocity to electron velocity.

In a cathode-ray tube having the following values:

Axial accelerating potential, volts -----	1,400
Axial electron velocity, m./sec. -----	2.22×10^7
Length of the deflection system axis, inches ---	3
Characteristic impedance, ohms -----	50

a deflection system of the type disclosed was used with the following values:

$$\begin{aligned} w &= 0.023 \text{ in.} \\ b &= 0.005 \text{ in.} \\ s &= 0.005 \text{ in.} \\ a &= 0.374 \text{ in.} \\ d &= 0.1 \text{ in.} \end{aligned}$$

Heretofore, we have discussed the use of a single folded strip in an unbalanced single-ended system. FIGURE 3 shows the use of two similar folded strips 10 and 13 in a balanced double-ended deflection system. In this system the two strips 10 and 13 are separated by a distance d' and the electron stream flowing therethrough is deflected by the fields created by both strips. Balanced deflection signals of equal amplitude but opposite polarity may be applied to the ends of the two strips at the start of the deflection region. All the parameters of the single-ended system set forth above apply to the double-ended

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system except that the impedance is now determined by that of a broadside-coupled strip line. Plates 11 and 12 are disposed preferably parallel to strips 10 and 13 respectively and are separated therefrom by distances b and b' respectively. Preferably b and b' are made equal for purposes of symmetry.

For spacings d' substantially greater than the distances b and b' , this system has a 100-ohm impedance when the ratio of w/b is approximately one-half that of the single-ended system of FIGURE 1, and the values of the other design parameters such as the spacing s between adjacent portions and the thickness t of each strip are the same as those of the single-ended system.

Although we have shown the folded strip lines 10 and 13 to be rectilinear throughout, this is not necessary to practice our invention. Curved or U-shaped ends may be used to interconnect adjacent portions and the portions themselves need not be at right angles to the end pieces. They may be slanted to the direction of the electron stream as long as the central portion, thereof, in the vicinity of the electron stream are equidistant from each other and lie in a common plane. Such a configuration is shown in FIGURE 4.

For additional strength and ease of mounting within the cathode-ray tube, a dielectric material (not shown) may be attached to the end portions 14 and 20 of strip line 10. If such a dielectric support is used, the characteristics of the strip line 10 may be altered slightly, particularly the impedance, but this may be compensated for in accordance with the principles of our invention set forth above.

Other and further modifications will occur to those skilled in the art and all such are considered to fall within the spirit and scope of our invention as defined in the appended claims.

We claim:

1. An electron stream deflection system of the traveling-wave transmission-line type for use in a cathode-ray device having means for applying deflection signals to said system, comprising:

a folded, conductive, substantially planar strip having successive portions of substantially equal length disposed parallel to each other and a predetermined distance s apart, said strip being disposed adjacent to the electron stream so that the stream sequentially passes each of said successive portions;

a first planar electrode disposed parallel to said strip a predetermined distance b therefrom and on the side thereof remote from said electron stream, the ratio of s to b being equal to or greater than one; and

a second planar electrode displaced a greater distance from said strip than said first electrode and disposed on the opposite side of the electron stream from said strip.

2. An electron stream deflection system of the traveling-wave transmission-line type for use in a cathode-ray device having means for applying deflection signals to said system, comprising:

a thin, uniformly folded, conductive, substantially planar strip having successive portions of substantially equal length disposed parallel to each other and a predetermined distance s apart, said strip being disposed adjacent to the electron stream with the said portions perpendicular to the path of the electron stream, the width of each portion being approximately five times the said predetermined distance s ;

a first planar electrode disposed parallel to said strip a predetermined distance b therefrom and on the side thereof remote from said electron stream, the ratio of s to b being equal to or greater than one; and

a second planar electrode disposed parallel to said strip on the opposite side of the electron stream therefrom, said second electrode being displaced a greater distance from the strip than said predetermined distance.

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3. A balanced electron stream deflection system for use in a cathode-ray device having means for applying balanced deflection signals of substantially equal amplitude and opposite polarity to said system, comprising:

- a pair of similar, traveling-wave transmission-line deflectors positioned parallel to each other on opposite sides of the electron stream, each deflector having a folded, conductive, substantially planar strip with successive portions of substantially equal length disposed parallel to each other and a predetermined distance *s* apart, said strip being disposed adjacent to the electron stream, so that the stream sequentially passes each of said successive portions; and
- a planar electrode disposed parallel to each of said strips a predetermined distance *b* therefrom on the side thereof remote from said electron stream, the ratio of *s* to *b* being equal to or greater than one.

4. A balanced electron stream deflection system as in claim 3 in which the strips of the two deflectors are separated by a distance greater than said predetermined distance *b*.

5. A balanced electron stream deflection system as in claim 4 in which said predetermined distance *s* between

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said successive portions of said strips is less than the width of each portion measured in the direction of the flow of the electron stream.

6. A balanced electron stream deflection system as in claim 4 in which said predetermined distance *s* between said successive portions of said strips is approximately one-fifth the width of each portion measured in the direction of the flow of the electron stream.

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